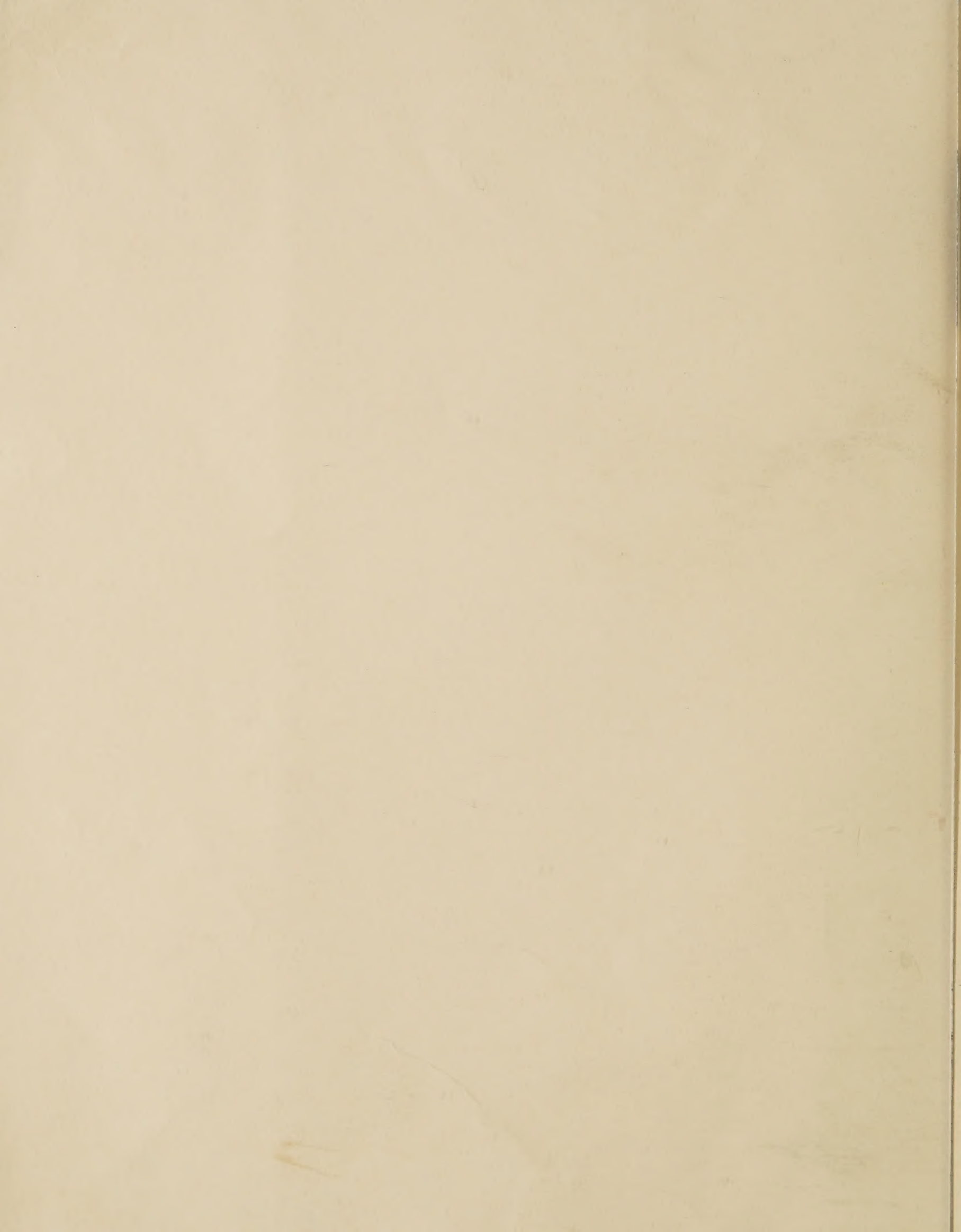




Public Roads

A JOURNAL OF HIGHWAY RESEARCH



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THE BUREAU OF
PUBLIC ROADS,
U. S. DEPARTMENT
OF COMMERCE,
WASHINGTON

Increasing traffic needs many improvements
such as this one on U S 40 in California

Public Roads

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BUREAU OF PUBLIC ROADS

U. S. DEPARTMENT OF COMMERCE

E. A. STROMBERG, Editor

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Traffic Trends on Rural Roads in 1949

BY THE HIGHWAY TRANSPORT RESEARCH BRANCH
BUREAU OF PUBLIC ROADS

Reported by THOMAS B. DIMMICK, Head,
Current Data Analysis Unit

Total travel on rural roads in 1949 broke records, exceeding the 1948 previous high by 7 percent and the prewar peak by 27 percent. On the 350,000 miles of main rural roads in the United States, travel in 1949 was over 159 billion vehicle-miles, of which 78 percent was by passenger cars, 1 percent by buses, and 21 by freight-carrying vehicles. Trucks and combinations hauled 7 percent more ton-mileage of freight in 1949 than in 1948 and 52 percent more than in 1941, the increase resulting largely from greater use of heavier vehicles. Truck-combination travel was 10 percent higher than in 1948, 85 percent higher than in 1941, and 24 percent higher than in 1936. Comparable figures for single-unit trucks were 5, 2 and 92 percent. The average carried load for all trucks and combinations in 1949 was 2, 40, and 76 percent above the averages in 1948, 1941, and 1936, respectively.

In 1949 more than 5 percent of all trucks and combinations exceeded a State legal weight limit, and 16 percent of the combinations were illegally overloaded in some particular. In comparison with 1948, the percentage of overweight vehicles decreased slightly in 1949 except in the western States.

MOTOR-VEHICLE TRAVEL in 1949 broke all previous records for the fourth consecutive year. The 1949 traffic on all rural roads was 7 percent higher than in 1948, 1 percent higher than in 1947, and about 27 percent above the 1946 volume and the 1941 prewar peak. Geographically the increases over 1948 ranged from 4 percent in the western States to 9 percent in the eastern States, with an average increase in the central States of 7 percent. The largest increase in any of the United States census regions¹ was 12 percent in the West North Central region and the smallest increase was 1 percent in the Pacific region. Records from about 800 automatic traffic recorders, operated continuously throughout the year at permanent stations on main and local roads in all States, were used generally to establish these trends. More extensive traffic surveys, made by a number of States, yielded valuable information concerning the total volume of rural traffic within their boundaries. Consideration has been given to all such available data in this analysis. Where States have prepared and submitted vehicle-mile travel estimates of their own, these have been employed rather than estimates made by applying trend factors.

¹The States comprising each census region are indicated in table 1.

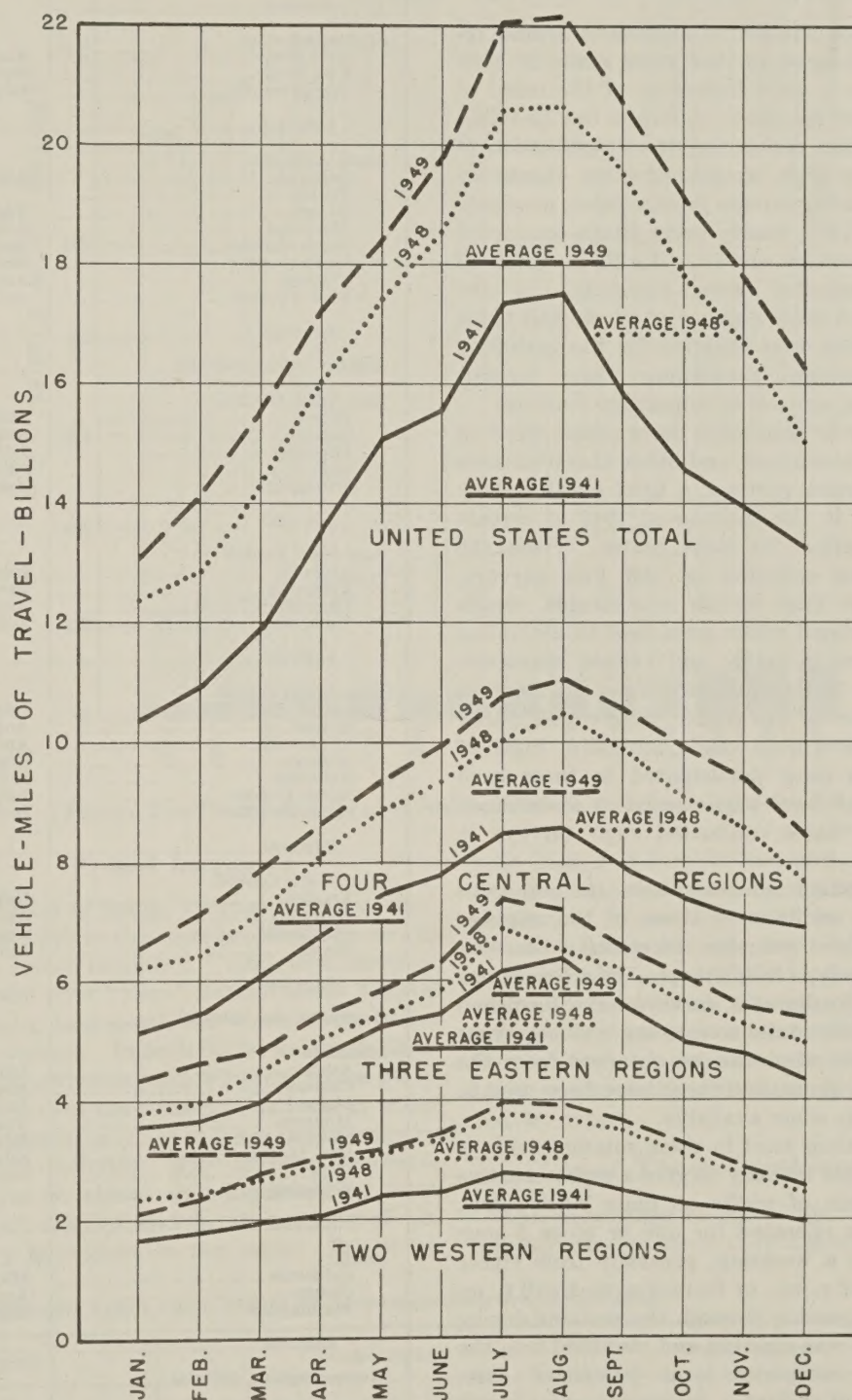


Figure 1.—Travel on all rural roads in 1941, 1948, and 1949, by months.

The variation in travel on rural roads in three main geographic divisions and in the United States as a whole is illustrated in figure 1 for the years 1949, 1948, and 1941, the latter being the prewar peak year. Travel in each month of 1949 in the eastern and central regions and in the United States as a whole was well above that of the corresponding

month of the earlier years. The western regions, however, showed only a slight increase from 1948 to 1949.

Summer travel in 1949 reached its prewar importance for the first time since the end of hostilities in 1945. In the last two prewar years the average monthly travel in July and August was 23 percent above that of the

average month of the year. Restrictions placed on nonessential driving in 1942 reduced travel in the summer months so that only 13 or 14 percent more traffic used the roads in the summer months than in the average month of the war years. Following the war this seasonal travel increased each succeeding year. Not until 1949, however, did vacation and other summer driving again reach the prewar level, 23 percent above the annual average.

1949 Summer Loadometer Survey

The large number of automatic traffic recorders operated on the rural roads of each State gives a good indication of the trend of total traffic on those highways but provides no indication concerning the classification of vehicles by type, weight, or other characteristics. During certain prewar years, generally 1936 and 1937, nearly every State conducted a comprehensive survey of traffic in which all vehicles counted were classified. At the same time a large number of trucks and truck combinations were stopped for the gathering of information concerning their weight, dimensions, and other important features.

In order to determine the wartime trend in weights, dimensions, and other characteristics of commercial vehicles, a brief check survey was made in the summer of 1942 at certain typical stations in most States. From the information collected in the two surveys, which were kept strictly comparable, trends were calculated which were used to determine the changes in traffic and vehicle characteristics that had taken place since the comprehensive survey was made. Since 1942, check surveys have been made annually; most of the States have participated in these each year and all have participated at some time.² Forty-six States conducted such surveys in 1949.

Classification counts made in numerous States, in addition to those of the summer survey, added valuable information concerning vehicle-type frequencies. In a few States expanded loadometer surveys have furnished more reliable data concerning vehicle types and weights than can be obtained from the trend data alone, and these have been used in the analysis when available.

The stations used in these summer surveys were selected initially to give a representative cross section of traffic on main rural roads. They were operated for one or more 8-hour periods on a weekday, generally from either 6 a. m. to 2 p. m., or from 2 p. m. to 10 p. m. All traffic passing through the stations during the period was counted and classified into the following categories: local passenger cars; foreign (out-of-State) passenger cars; panel and pickup trucks;³ other two-axle, four-tire trucks; truck-tractor and semitrailer combinations; truck and trailer combinations or

Table 1.—Survey period, number of stations operated, number of vehicles counted, and number weighed in each State in the special weight surveys, summer of 1949

Region and State	Survey period	Number of stations	Total vehicles counted	Trucks and truck combinations	
				Counted	Weighed
New England:					
Connecticut.....	Aug. 1-12.....	10	32,760	5,817	2,430
Maine.....	July 21-Aug. 5.....	10	24,308	4,252	2,018
Massachusetts.....	Aug. 8-26.....	10	36,083	5,685	1,925
New Hampshire.....	Aug. 8-12.....	5	15,282	1,814	496
Rhode Island.....	July 25-Aug. 1.....	5	14,322	2,400	1,145
Vermont.....	Aug. 1-5.....	5	10,002	651	651
Subtotal.....		45	132,757	20,619	8,665
Middle Atlantic:					
New Jersey.....	Aug. 16-Sept. 8.....	10	79,674	14,873	1,977
New York.....	Sept. 19-24.....	20	39,380	10,265	3,464
Pennsylvania.....	July 26-Sept. 1.....	7	24,066	4,818	907
Subtotal.....		37	143,120	29,956	6,348
South Atlantic:					
Delaware.....	Aug. 11-25.....	9	26,819	7,922	1,194
Florida.....	(¹).....				
Georgia.....	Aug. 1-30.....	12	17,383	4,384	3,024
Maryland.....	Aug. 8-15.....	10	39,267	8,001	1,151
North Carolina.....	Aug. 9-30.....	12	36,228	6,311	4,324
South Carolina.....	Sept. 12-26.....	10	17,162	4,659	2,111
Virginia.....	Aug. 3-19.....	10	22,279	5,099	3,811
West Virginia.....	Aug. 9-Sept. 2.....	9	13,170	3,134	1,301
Subtotal.....		72	172,308	39,510	16,924
Eastern regions, subtotal.....		154	448,185	90,085	31,937
East North Central:					
Illinois.....	Aug. 23-Sept. 7.....	47	85,148	17,143	6,444
Indiana.....	Aug. 3-31.....	20	44,232	10,375	4,151
Michigan.....	July 22-Aug. 4.....	8	21,928	2,930	1,021
Ohio.....	July 26-Aug. 11.....	10	26,244	4,891	1,041
Wisconsin.....	Aug. 4-25.....	10	24,945	3,755	1,281
Subtotal.....		95	202,497	39,094	13,961
East South Central:					
Alabama.....	July 13-29.....	10	11,594	2,910	1,774
Kentucky.....	June 20-July 6.....	10	12,959	2,925	1,151
Mississippi.....	Aug. 15-Sept. 2.....	15	24,253	6,633	2,611
Tennessee.....	Aug. 2-16.....	10	11,336	3,011	1,771
Subtotal.....		45	60,142	15,479	7,247
West North Central:					
Iowa.....	July 25-Aug. 5.....	10	13,336	2,427	2,441
Kansas.....	Aug. 11-24.....	10	10,566	2,141	1,081
Minnesota.....	Apr. 11-Aug. 3.....	10	29,075	6,492	2,141
Missouri.....	Aug. 12-Sept. 1.....	15	70,079	14,323	6,941
Nebraska.....	July 21-Aug. 17.....	20	22,014	4,744	4,581
North Dakota.....	July 21-Sept. 1.....	15	22,960	5,376	2,041
South Dakota.....	June 24-Sept. 21.....	11	8,956	1,391	1,141
Subtotal.....		91	176,986	36,894	20,441
West South Central:					
Arkansas.....	July 25-Aug. 5.....	10	16,804	5,519	1,441
Louisiana.....	July 18-27.....	10	10,015	3,019	1,141
Oklahoma.....	Aug. 15-29.....	10	14,414	3,139	3,041
Texas.....	June 15-Sept. 13.....	17	29,982	6,838	1,641
Subtotal.....		47	71,215	18,515	7,241
Central regions, subtotal.....		278	510,840	109,982	48,841
Mountain:					
Arizona.....	June 6-17.....	10	9,010	1,962	741
Colorado.....	Aug. 11-29.....	10	25,647	4,161	441
Idaho.....	July 25-Aug. 10.....	13	15,429	2,886	2,741
Montana.....	Aug. 3-Sept. 1.....	19	16,344	3,197	2,841
Nevada.....	July 25-Aug. 9.....	10	6,693	1,036	841
New Mexico.....	July 21-Aug. 4.....	10	12,621	2,739	1,241
Utah.....	July 18-Aug. 5.....	10	16,112	3,215	1,441
Wyoming.....	(¹).....				
Subtotal.....		82	101,856	19,196	10,341
Pacific:					
California.....	May 31-June 30.....	20	71,484	13,153	4,841
Oregon.....	Aug. 9-19.....	8	15,660	2,893	1,141
Washington.....	June 7-Oct. 7.....	20	99,978	18,007	12,441
Subtotal.....		48	187,122	34,053	19,041
Western regions, subtotal.....		130	288,978	53,249	29,341
United States total.....		562	1,248,003	253,316	110,041

¹ No survey made.

² Passenger cars not counted; figure given is an estimate based on data from other reports.

truck-tractor semitrailer and trailer combinations; and busses. The combination-type vehicles were further subdivided according to the number of axles of each.

Most of the weight stations were operated during July, August, and September. Arizona completed its work in June; California started its survey on the last day in May and

completed it in June; Texas operated its stations from June to September; Washington conducted its operations from June to October.

The survey period, number of stations operated, number of vehicles counted, and number weighed are shown for each State in table 1. Almost 1¼ million vehicles were counted at all stations during the period of the

² See *Traffic trends on rural roads*, by T. B. Dimmick, PUBLIC ROADS, vol. 25, No. 12, Feb. 1950; vol. 25, No. 7, Mar. 1949; vol. 25, No. 3, Mar. 1948; vol. 24, No. 10, Oct.-Nov.-Dec. 1946; and *Amount and characteristics of trucking on rural roads*, by J. T. Lynch and T. B. Dimmick, PUBLIC ROADS, vol. 23, No. 9, July-Aug.-Sept. 1943.

³ Single-unit trucks with a carrying capacity of less than 1½ tons.

vey. About one-fifth of these were freight-carrying vehicles, of which almost one-half we weighed.

Wherever traffic volume permitted, every truck and truck combination was stopped and weighed. Where this procedure was impracticable all of the less common types were weighed and the common vehicle types were weighed in sufficient numbers to establish their characteristics from the sample. The type of vehicle, whether loaded or empty, the number of axles, and the weight of each axle were recorded. The axle-spacing and total wheelbase length of the heavier vehicles⁴ were measured, and the commodity carried and the type of operation—private or for-hire—were recorded. Passenger cars and busses were counted but not stopped for weighing.

Prewar Travel Trend Maintained

Figure 2 shows in chart form the vehicle-mileage of travel on all rural roads, by type of vehicle, for each year from 1936 to 1949, inclusive. It is apparent that the effect of the drastic restriction of travel during the war period, 1942-45, has now been entirely overcome. A straight line from the top of the bar for 1936 to the top of the bar for 1949 passes through the tops of the bars for 1937, 1939, and 1940, and only slightly above the top of the bar for 1938 and slightly below that of 1941. The recession in business activity in 1938 probably accounts for the lessened volume of traffic in that year; and 1941 was a year of exceptional activity in preparation for the war that followed. Altogether, total traffic has recovered completely from the effect of the war and stands, as near as can be determined from the long-time trend, at a level which would have been reached had the war not occurred.

In the case of travel of trucks and truck combinations,⁵ the 1949 value fits the 1936-40 trend, projected, almost exactly. For truck combinations alone, the 1936-48 line lies slightly above the tops of the bars for all intervening years. This and other trend data indicate an accelerating growth in traffic by vehicles of this type.

Trucks and truck combinations weighing 13 tons or more having an axle weighing 18,000 pounds or more.

In this article, the term "truck" is used to indicate a single-unit vehicle; "truck combination" to indicate truck and semitrailer (with or without full trailer) and truck with full trailer; and "trucks and truck combinations" to indicate all of these vehicles together.

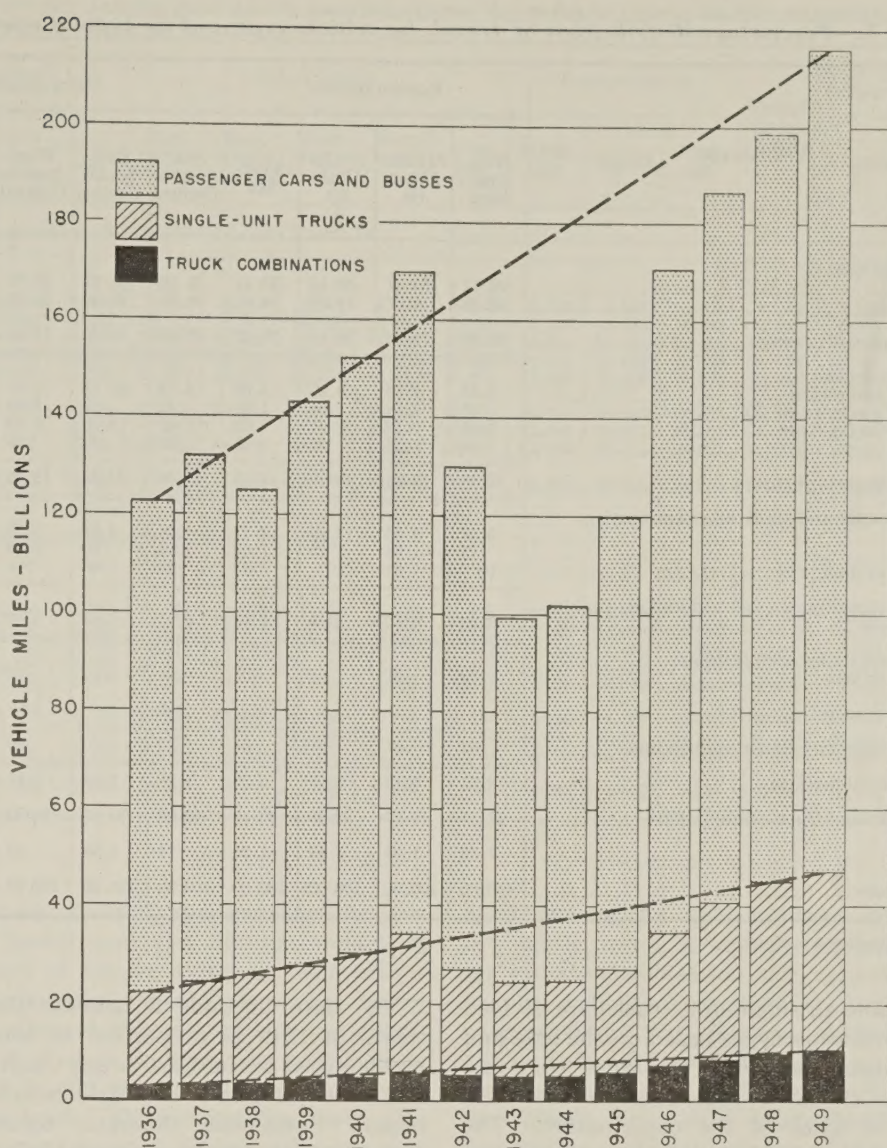


Figure 2.—Travel on all rural roads, 1936-49, by classes of vehicles.

Travel Increases

The ratio of traffic volumes on main rural roads in 1949 to the corresponding volumes in 1948 is shown in table 2. Highways classified under the term "main" include about 350,000 miles and, in general, are those of the entire State systems. In such States as North Carolina, Pennsylvania, and Virginia, where all or a large part of the rural-road mileage is under State control, only the mileage in the primary system is included. The consistent increase in travel on these main highways by most types of vehicles and in all sections of the country is evident in the table. Travel by

both local and foreign (out-of-State) passenger cars increased in all regions, but travel by single-unit trucks decreased in the Middle Atlantic, South Atlantic, and Pacific regions and increased only slightly in the New England and West South Central regions. The increases in travel by truck combinations and the decreases by single-unit trucks appear to be a result of the continued shifting to the heavier types.

Use of Truck Combinations

The percentage of travel by vehicle types on main rural roads in 1949 is given in table 3.

Table 2.—Ratio of 1949 traffic on main rural roads to corresponding traffic in 1948¹

Vehicle type	Eastern regions				Central regions					Western regions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
Passenger cars:													
Local	1.09	1.15	1.08	1.11	1.07	1.01	1.09	1.10	1.08	1.08	1.04	1.05	1.08
Foreign	1.15	1.09	1.15	1.13	1.03	1.33	1.08	1.17	1.10	1.05	1.03	1.04	1.10
All passenger cars	1.11	1.13	1.10	1.12	1.06	1.10	1.09	1.12	1.09	1.07	1.04	1.05	1.09
Trucks and truck combinations:													
Single-unit trucks	1.01	.85	.99	.93	1.09	1.10	1.08	1.02	1.07	1.08	.84	.96	1.05
Truck combinations	1.10	1.17	1.31	1.22	1.02	1.11	1.06	1.05	1.04	1.30	1.26	1.27	1.10
All trucks and truck combinations	1.03	.93	1.06	1.01	1.06	1.10	1.07	1.03	1.06	1.12	.95	1.07	1.06
Busses	.75	.99	.99	.95	.87	1.06	.84	1.02	.94	.94	.97	.96	.95
All vehicles	1.09	1.09	1.09	1.09	1.06	1.10	1.08	1.09	1.08	1.08	1.02	1.06	1.08

¹ The ratios for "all vehicles" are based on year-round automatic recorder data, while those for the individual vehicle types are based principally on summer counts.

Table 3.—Percentage distribution of travel, by vehicle type and by type of operation, on main rural roads in the summer of 1949

Vehicle type	Eastern regions				Central regions					Western regions			United States average	U. S. percentage distribution of trucks and truck combinations by type of operation	
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average		Private	For hire
Passenger cars:															
Local.....	56.11	63.31	57.15	59.61	58.56	45.37	59.79	58.84	57.13	41.75	76.14	63.83	59.12	-----	-----
Foreign.....	25.38	16.07	19.03	18.66	20.74	22.46	15.41	15.04	18.37	34.24	10.56	19.04	18.58	-----	-----
All passenger cars.....	81.49	79.38	76.18	78.27	79.30	67.83	75.20	73.88	75.50	75.99	86.70	82.87	77.70	-----	-----
Single-unit trucks:															
Panel and pickup.....	5.31	4.35	6.89	5.60	5.32	12.11	7.05	10.02	7.77	9.76	3.36	5.65	6.69	40.36	1.68
Other 2-axle, 4-tire.....	.65	1.18	1.04	1.04	.42	.57	1.02	.37	.57	.79	.52	.62	.73	4.38	.33
Other 2-axle, 6-tire.....	7.16	7.49	7.91	7.63	6.62	11.70	9.79	7.90	8.35	6.99	3.54	4.77	7.49	39.18	22.36
3-axle.....	.34	.42	.35	.38	.32	.22	.26	.18	.26	.36	.54	.48	.33	1.45	2.03
All single-unit trucks.....	13.46	13.44	16.19	14.65	12.68	24.60	18.12	18.47	16.95	17.90	7.96	11.52	15.24	85.37	26.40
Truck-tractor and semitrailer combinations:															
3-axle.....	3.58	5.05	4.89	4.77	4.58	4.85	3.33	4.65	4.34	1.74	.77	1.11	3.92	10.43	45.86
4-axle.....	.15	1.06	1.29	1.03	2.14	.80	2.09	1.67	1.83	1.34	.85	1.02	1.43	3.02	19.31
5-axle or more.....	(1)	.01	(1)	.01	.23	.02	.19	.04	.15	.86	1.36	1.19	.28	.40	4.40
All truck-tractor and semitrailer combinations.....	3.73	6.12	6.18	5.81	6.95	5.67	5.61	6.36	6.32	3.94	2.98	3.32	5.63	13.85	69.63
Truck and trailer combinations:															
4-axle or less.....	.02	.01	.01	.01	.05	(1)	.20	.17	.11	.23	.22	.22	.10	.39	.64
5-axle.....	-----	-----	-----	-----	.17	-----	(1)	.01	.07	.34	.39	.38	.10	.18	1.40
6-axle or more.....	-----	-----	-----	-----	.11	-----	(1)	-----	.04	.32	.73	.58	.12	.21	1.80
All truck and trailer combinations.....	.02	.01	.01	.01	.33	(1)	.20	.18	.22	.89	1.34	1.18	.32	.78	3.90
All combinations.....	3.75	6.13	6.19	5.82	7.28	5.67	5.81	6.54	6.54	4.83	4.32	4.50	5.95	14.63	73.60
All trucks and truck combinations.....	17.21	19.57	22.38	20.47	19.96	30.27	23.93	25.01	23.49	22.73	12.28	16.02	21.19	100.00	100.00
Busses.....	1.30	1.05	1.44	1.26	.74	1.90	.87	1.11	1.01	1.28	1.02	1.11	1.11	-----	-----
All vehicles.....	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	-----	-----

¹ Less than 0.005 percent.

In this table all single-unit trucks are divided into classification types based on the axle and tire arrangements, while the truck combinations are classified according to the total number of axles of the combination. The classification of vehicles into these types has been used only in the last three annual surveys. It has several advantages over the old "light, medium, and heavy" grouping, among which are more homogeneous groupings and more positive identification of the types.

The data in table 3 indicate that truck travel in 1949 in proportion to total travel was heaviest in the East South Central region and next heaviest in the West South Central region. Somewhat different figures were found in 1948: the West South Central region then had the highest percentage of truck traffic, followed by the West North Central and South Atlantic regions. The percentage of truck traffic in the South Atlantic, East South Central, West North Central, West

South Central, and Mountain regions exceeded 20 percent of the total traffic in both 1948 and 1949. More urbanized areas, such as the New England, Middle Atlantic, and Pacific regions, where total traffic is rather heavy, have the smallest percentage of truck travel. The table indicates that certain types of vehicles are popular in some sections. For instance, the truck and trailer combinations with six or more axles and the truck-tractor and semitrailer combinations with five or more

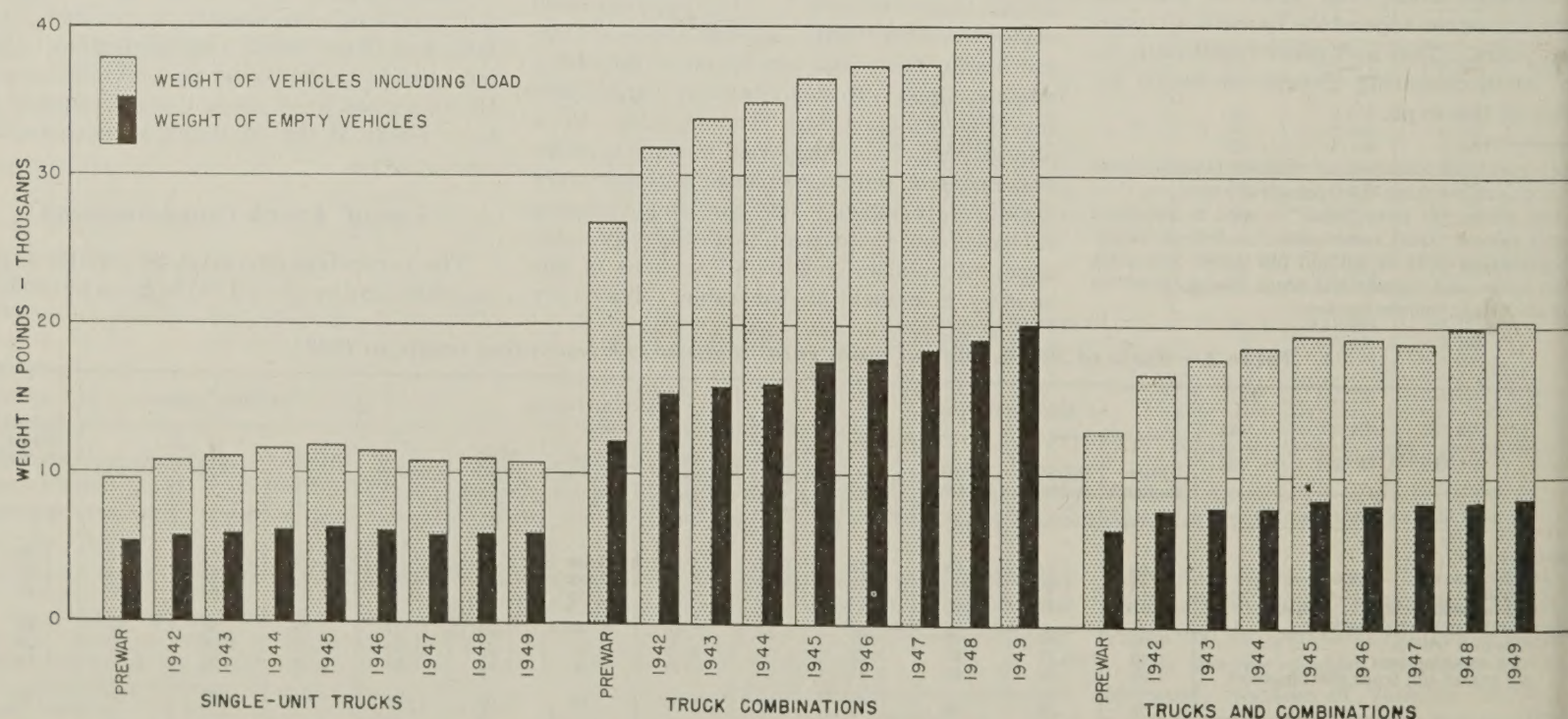


Figure 3.—Average weights of loaded and of empty trucks and truck combinations in the summers of 1942-49 and in a corresponding period of a prewar year.

Table 4.—Average weights (in pounds) of loaded and empty trucks and truck combinations, by vehicle types, in the summer of 1949

Vehicle type	Eastern regions				Central regions					Western regions			United States average	U. S. average by type of operation	
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average		Private	For-hire
AVERAGE WEIGHTS OF LOADED VEHICLES															
Single-unit trucks:															
Panel and pickup.....	4,901	5,409	4,756	5,015	5,041	5,111	5,154	5,907	5,362	5,695	4,524	5,100	5,242	5,208	6,702
Other 2-axle, 4-tire.....	6,201	6,278	6,301	6,281	6,571	6,974	6,621	6,883	6,677	7,133	5,803	6,302	6,447	6,358	10,221
Other 2-axle, 6-tire.....	14,343	15,159	13,307	14,196	13,007	13,611	13,674	12,959	13,294	14,990	12,262	13,514	13,614	13,233	15,789
3-axle.....	30,595	33,616	27,675	30,716	27,734	28,635	25,951	28,101	27,433	26,728	25,635	25,880	28,128	27,484	29,081
Average.....	11,352	12,660	10,716	11,565	10,339	10,879	10,920	9,213	10,310	11,486	10,380	10,879	10,765	10,150	16,222
Truck combinations:															
Truck-tractor and semitrailer.....	37,158	42,105	37,898	39,629	37,322	34,364	39,135	36,211	37,100	45,621	48,550	47,405	39,151	37,255	40,173
Truck and trailer.....	39,471	60,366	(1)	48,506	69,361	34,364	18,109	18,495	47,099	62,642	58,613	59,451	55,458	42,182	64,321
Average.....	37,174	42,158	37,889	39,653	38,482	38,462	35,719	37,397	37,397	48,009	51,411	50,227	39,999	37,543	41,427
Average, all trucks and truck combinations.....	18,062	23,196	19,152	20,643	22,638	17,422	19,589	16,560	19,774	22,446	22,781	22,643	20,432	14,811	35,374
AVERAGE WEIGHTS OF EMPTY VEHICLES															
Single-unit trucks:															
Panel and pickup.....	4,035	4,383	3,851	4,039	3,971	4,078	4,205	4,446	4,189	4,141	3,824	4,038	4,121	4,099	4,784
Other 2-axle, 4-tire.....	5,074	4,992	5,126	5,048	4,836	5,044	5,271	5,139	5,102	5,285	4,585	4,971	5,057	5,018	7,131
Other 2-axle, 6-tire.....	8,651	8,966	7,310	8,182	7,668	7,728	8,059	7,692	7,784	8,285	7,482	7,978	7,942	7,828	8,636
3-axle.....	17,169	15,230	13,143	14,609	14,500	11,953	13,585	16,187	14,489	14,377	14,139	14,225	14,483	14,519	13,644
Average.....	6,448	6,895	5,424	6,108	5,885	5,529	6,033	5,991	5,864	5,553	5,572	5,560	5,903	5,724	8,716
Truck combinations:															
Truck-tractor and semitrailer.....	20,672	20,646	18,787	19,815	19,588	16,690	20,250	18,670	19,094	23,016	22,103	22,592	19,610	19,088	19,945
Truck and trailer.....	31,825	(1)	31,825	(1)	31,825	12,393	15,127	25,124	29,595	27,837	28,523	27,142	23,806	29,630	29,630
Average.....	20,672	20,646	18,784	19,814	20,389	16,690	19,906	18,579	19,330	24,722	24,296	24,503	20,019	19,314	20,546
Average, all trucks and truck combinations.....	8,811	9,782	7,694	8,655	10,119	6,781	8,852	8,673	8,700	8,142	8,832	8,406	8,648	7,252	16,484

Data omitted because of insufficient sample.

are used more frequently in the Pacific region than in any other area. Combinations involving trailers are used much less in the East South Central region and in the three Western regions. The percentage of travel by combinations has increased steadily over that in the previous years' samples, this percentage being 5.95 in 1949, 5.84 in 1948, 5.73 in 1947, and 5.26 in 1946.

Private and For-Hire Traffic

In the survey conducted in 1949 information was gathered in most of the participating States concerning the use-classification under which each vehicle was being operated. Data were reported separately for private and for-

hire vehicles of each type, showing the percentage loaded and the average weight of loaded and of empty vehicles. The operation-use classification of each of the heavy vehicles—those with one or more axles weighing 18,000 pounds or more, or with a gross weight of 26,000 pounds or more—generally was designated. This information made possible the calculating of vehicle-mileages, ton-mileages, and other data on the main rural roads by the various types of trucks and truck combinations privately operated and operated for-hire.

In the last two columns of table 3 are shown the percentage distribution of travel of all privately operated and for-hire trucks and

combinations, by vehicle type. In general the lighter types of vehicles predominate in the private classification and, conversely, the heavier vehicles constitute a much higher proportion of the for-hire vehicles. This difference is very noticeable in the percentages for the light panel and pickup trucks and for the heavy three-axle truck-tractors with semitrailers. Over 40 percent of the privately operated truck travel was by the panel and pickup type, while less than 2 percent of the for-hire vehicle travel was by this type. On the other hand, less than 15 percent of the travel of all privately operated vehicles was by truck combinations, while of the for-hire travel almost 74 percent was by combinations.

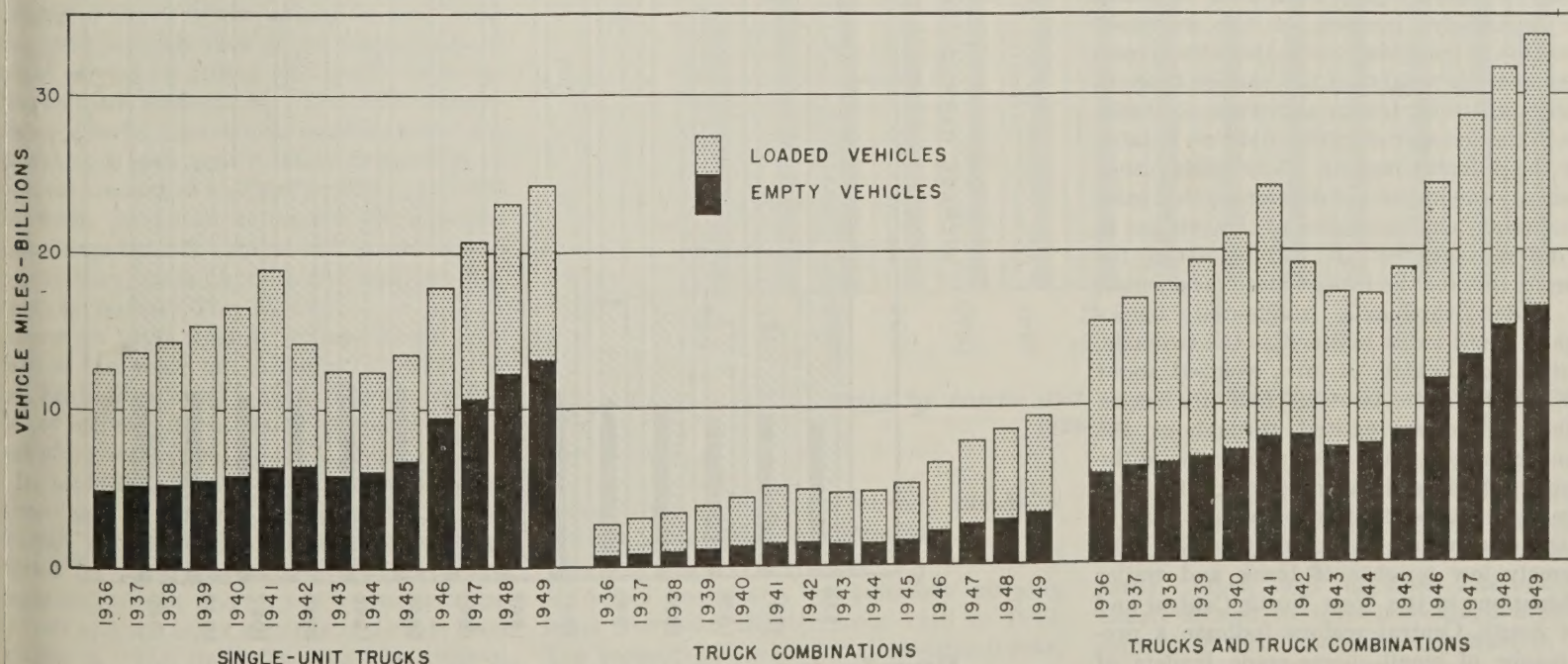


Figure 4.—Travel on main rural roads, 1936-49, by loaded and by empty trucks and truck combinations.

Table 5.—Comparison of estimated vehicle-miles of travel on main rural roads in 1936, 1941, 1946, 1948, and 1949

Year	All vehicles, vehicle-miles	Passenger cars and busses ¹		All trucks and truck combinations		Single-unit trucks		Truck combinations	
		Percentage of all vehicles	Vehicle-miles	Percentage of all vehicles	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles	Percentage of all trucks and truck combinations	Vehicle-miles
1936.....	Millions 88,412	82.6	73,005	17.4	15,407	82.1	12,650	17.9	2,757
1941.....	122,505	80.3	98,320	19.7	24,185	78.8	19,057	21.2	5,128
1941: 1936 ratio.....	1.39	.97	1.35	1.13	1.57	.96	1.51	1.18	1.86
1946.....	124,149	80.4	99,803	19.6	24,346	73.3	17,838	26.7	6,508
1946: 1941 ratio.....	1.01	1.00	1.02	.99	1.01	.98	1.94	1.26	1.27
1946: 1936 ratio.....	1.40	.97	1.37	1.13	1.58	.89	1.41	1.49	2.36
1948.....	147,597	78.5	115,837	21.5	31,760	72.9	23,138	27.1	8,622
1949.....	159,379	78.8	125,602	21.2	33,777	71.9	24,295	28.1	9,482
1949: 1948 ratio.....	1.08	1.00	1.08	.99	1.06	.99	1.05	1.04	1.10
1949: 1941 ratio.....	1.30	.98	1.28	1.08	1.40	.91	1.27	1.33	1.85
1949: 1936 ratio.....	1.80	.95	1.72	1.22	2.19	.88	1.92	1.57	3.44
COMPARISON FOR TRUCKS AND TRUCK COMBINATIONS, BY TYPE OF OPERATION									
Private:									
1936.....				78.8	12,140	86.7	10,963	42.7	1,177
1949.....				77.2	26,077	91.6	22,262	40.2	3,815
1949: 1936 ratio.....				.98	2.15	1.06	2.03	.94	3.24
For-hire:									
1936.....				21.2	3,267	13.3	1,687	57.3	1,580
1949.....				22.8	7,700	8.4	2,033	59.8	5,667
1949: 1936 ratio.....				1.08	2.36	.63	1.21	1.04	3.59

¹ Percentages of total 1949 travel by passenger cars and by busses are reported separately in table 3

Average Weights Increase

The average weights of loaded and empty trucks and truck combinations, separately and combined, are shown graphically in figure 3 for each year from 1942 to 1949, inclusive, and in a prewar year, generally 1936 or 1937. The weights of single-unit trucks, both loaded and empty, increased each year from the 1936-37 period through 1945, then leveled off or decreased slightly each succeeding year. At the same time weights of truck combinations, both loaded and empty, have increased each year during the period shown. The increase in average weight of loaded combinations from the 1936-37 period to 1949 was almost 50 percent, compared to only 12 percent for single-unit trucks. The increase for all trucks and truck combinations combined was 57 percent, a figure higher than that of either type separately, because of the increased proportion of combinations in the latter years.

The average weights of the various types of loaded and empty trucks and truck combinations in the summer of 1949 are shown in table 4 for the different regions. This table brings out clearly the important differences that exist in the weight characteristics of the vehicles in the different groups. It will be noted, for example, that for the United States as a whole, the loaded three-axle, single-unit trucks weighed about twice as much as the two-axle, six-tire trucks which, in turn, weighed about twice as much as the two-axle, four-tire trucks. Similar differences existed throughout the various classifications. On the other hand the regional differences in average weight for each of the vehicle types that are common throughout the country are surprisingly small. The extremely low weights of truck and trailer combinations in the West North Central and West South Central regions indicate a predominance of small, home-made trailers of low capacity.

The average weights of loaded and empty trucks and truck combinations operated privately and for-hire in the summer of 1949 are shown in the last two columns of table 4. The for-hire vehicles, when compared by types, are generally heavier than those oper-

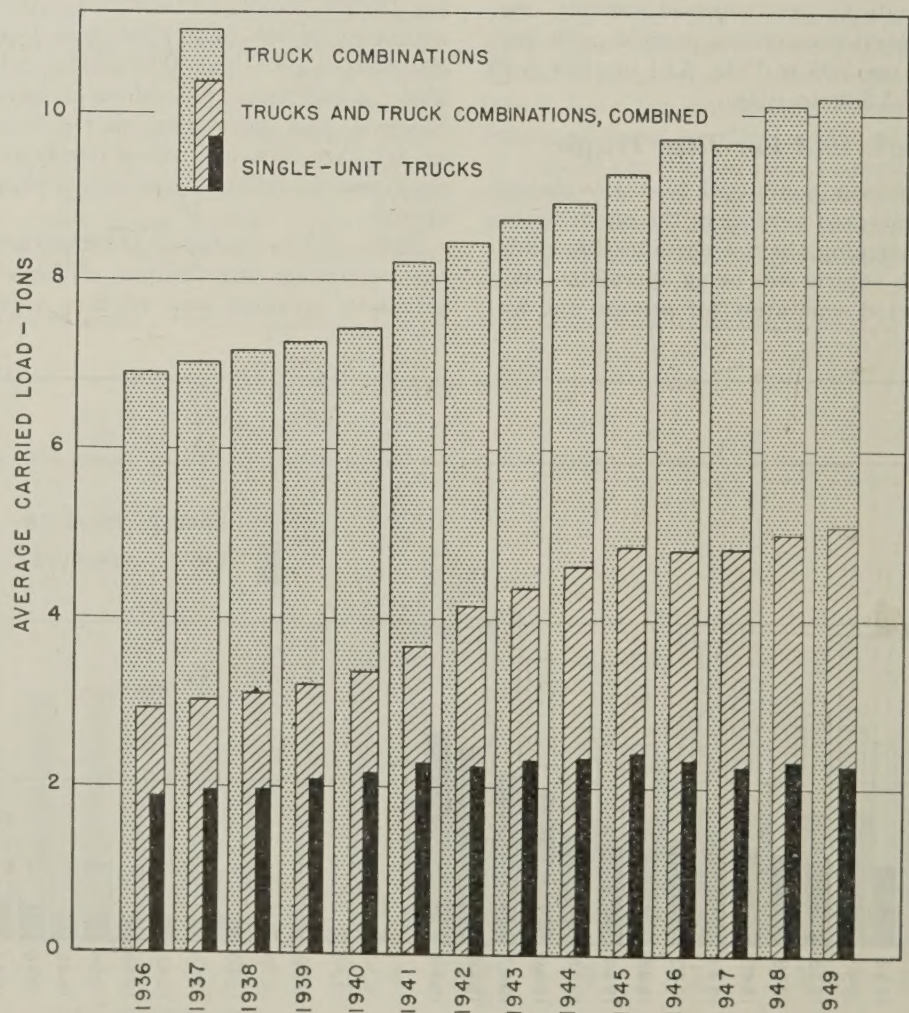


Figure 5.—Average load carried by trucks and truck combinations on main rural roads, 1936-49.

ated privately, and the average of all types of for-hire vehicles, either loaded or empty more than twice as heavy as the average of the privately operated vehicles. It was shown in table 3 that the largest portion of the private vehicles consisted of the small single-unit trucks while the greater portion of the for-hire vehicles consisted of the heavy truck combinations. This decided difference in distributions of sizes of vehicles in the two operation classes accounts for the great difference between their average weights.

Truck Travel Again Increases

Figure 4 shows a comparison of the estimated vehicle-mileage of travel by loaded and empty single-unit trucks and truck combinations, separately and combined, on main rural roads, for each year from 1936 to 1949, inclusive. This chart demonstrates graphically the steady growth of truck traffic during the prewar years, 1936-41, the temporary effect of wartime restrictions in the period 1942-45, and the remarkable increases in truck transportation that have occurred since the end of hostilities in 1945.

Table 5 shows a comparison of the estimated vehicle-mileage of travel by vehicles of different types on all main rural roads in 1936, the earliest year for which comprehensive weight data are available; in 1941, a peak prewar year, 5 years after the beginning of the surveys; in 1946, 10 years after the beginning of the surveys; and in 1948 and

The ratios of 1949 travel to that of the preceding years indicate that increases for trucks and truck combinations generally are greater than for passenger cars, and that increases for truck combinations were greater than for single-unit trucks. In the 13 years from 1936 to 1949, passenger-car and bus travel combined increased over 70 percent, travel by all trucks and combinations more than doubled, and travel by truck combinations (considered separately) more than tripled. The lower portion of table 5 shows a comparison of the estimated vehicle-mileage of travel in 1936 and in 1949 by privately operated trucks and combinations, and by those operated for-hire. Travel by for-hire vehicles increased somewhat more than travel by private vehicles, the 1949:1936 ratio being 1.15 in the case of for-hire vehicles and 2.15 in the case of private vehicles. Most of the increase in for-hire vehicle travel was by truck combinations, there being only a 21-percent increase in the for-hire vehicle-mileage by single-unit trucks compared to a 259-percent increase by combinations. In the case of the private vehicles, on the other hand, there were substantial increases in the vehicle-mileage by both types.

In the lower portion of table 5, incidentally, the percentage figures refer to trucks and truck combinations only; for example, of all single-unit trucks, in 1936, 86.7 percent were in private operation and 13.3 percent for-hire.

Volume of Highway Freight

Figure 5 gives a comparison of the average load carried by single-unit trucks and truck combinations, separately and combined, in the 13 years that the planning surveys have been operating. The general trend of load weights was upward throughout the period. The slight decline in the weights of loads carried by single-unit trucks since 1945 has been more than offset by the increased use of combinations and the increased weights of loads carried by vehicles of this type.

Figure 6 shows a comparison for each year from 1936 through 1949 of the ton-mileage of freight carried by trucks and truck combinations on main rural roads. The chart demonstrates clearly that truck combinations are transporting each year a larger proportion of the total amount of highway freight. In 1936 the truck combinations hauled slightly less ton-mileage than the single-unit trucks, while in 1949 they hauled almost two and one-half times as much. The rapid rate of annual increase in total freight carried, which took place in the years immediately following the war, has been reduced in the last two years to a rate of increase more nearly comparable with that of prewar years.

In table 6 is shown a comparison of the percentage of vehicles carrying loads, the average carried load, and the ton-mileage carried for all trucks and combinations, for single-unit trucks, and for truck combinations in 1949 and the other significant periods used in table 5. The trend from 1936 to 1949 of average weight carried, shown graphically in figure 5, and that of the ton-mileage trans-

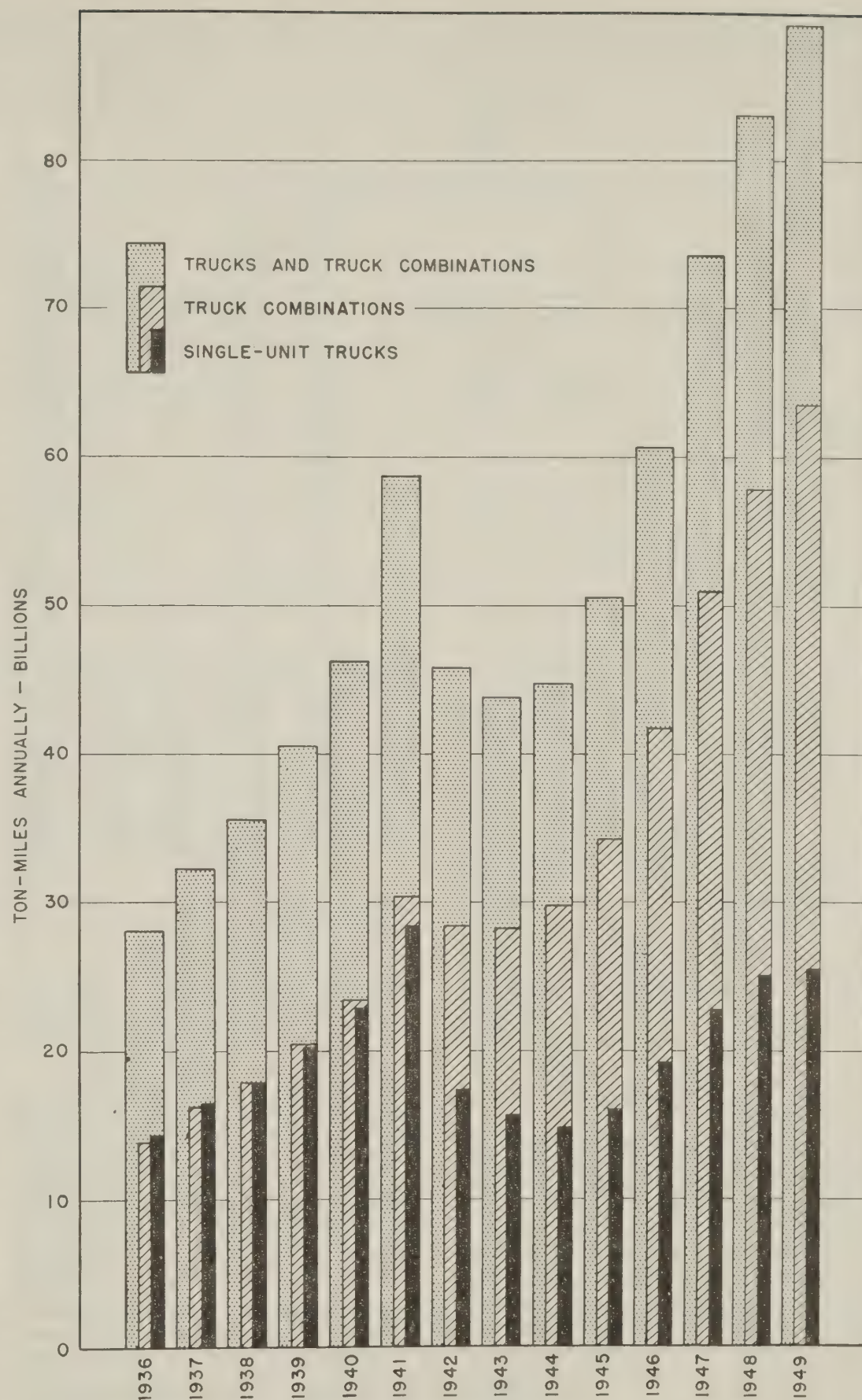


Figure 6.—Ton-miles carried by trucks and truck combinations on main rural roads, 1936-49.

ported during the same period, shown in figure 6, have already been discussed.

In the country as a whole, the percentage of trucks and truck combinations carrying loads decreased slightly from 1948 to 1949. The percentage loaded for single-unit trucks, for truck combinations, and for the two types of vehicles combined was less than the com-

parable figures for 1946, when the downward trend in these figures that had been maintained during the war appeared to be halted temporarily. Since 1946 the trend has not been clearly defined, for these percentages increased slightly in 1947 and then decreased in 1948 and again in 1949. With these latest decreases the proportion of vehicles loaded

Table 6.—Comparison of the estimated percentage of trucks and truck combinations loaded, average carried load, and ton-miles carried on main rural roads in 1936, 1941, 1946, 1948, and 1949, and similar data for privately operated and for-hire vehicles

Year	All trucks and truck combinations			Single-unit trucks			Truck combinations		
	Per-centage loaded	Average weight of carried load	Ton-miles carried	Per-centage loaded	Average weight of carried load	Ton-miles carried	Per-centage loaded	Average weight of carried load	Ton-miles carried
		Tons	Mil-lions		Tons	Mil-lions		Tons	Mil-lions
1936	62.8	2.90	28,005	60.7	1.86	14,258	72.2	6.90	13,747
1941	66.7	3.64	58,737	65.4	2.29	28,487	71.6	8.23	30,250
1941:1936 ratio	1.06	1.26	2.10	1.08	1.23	2.00	.99	1.19	2.20
1946	51.7	4.84	60,892	46.4	2.31	19,101	66.2	9.70	41,791
1946:1941 ratio	.78	1.33	1.04	.71	1.01	.67	.92	1.18	1.38
1946:1936 ratio	.82	1.67	2.17	.76	1.24	1.34	.92	1.41	3.04
1948	52.2	5.02	83,119	46.8	2.33	25,219	66.5	10.10	57,900
1949	51.6	5.11	89,100	46.1	2.29	25,639	65.7	10.19	63,461
1949:1948 ratio	.99	1.02	1.07	.99	.98	1.02	.99	1.01	1.10
1949:1941 ratio	.77	1.40	1.52	.70	1.00	.90	.92	1.24	2.10
1949:1936 ratio	.82	1.76	3.18	.76	1.23	1.80	.91	1.48	4.62
Privately operated trucks and truck combinations:									
1936	60.3	2.20	16,094	59.8	1.71	11,180	65.5	6.37	4,914
1949	47.6	3.48	43,231	45.3	2.10	21,193	61.2	9.43	22,038
1949:1936 ratio	.79	1.58	2.66	.76	1.23	1.90	.93	1.48	4.48
For-hire trucks and truck combinations:									
1936	71.9	5.07	11,911	66.4	2.73	3,078	77.3	7.23	8,833
1949	65.1	9.16	45,869	55.1	3.97	4,446	68.7	10.65	41,423
1949:1936 ratio	.91	1.81	3.85	.83	1.45	1.44	.89	1.47	5.03

reached a new all-time low level, only 46 percent of the single-unit trucks and less than 66 percent of the truck combinations being loaded in 1949, compared to 61 percent and 72 percent, respectively, for these two types of vehicles in 1936.

The lower portion of table 6 shows a comparison of the percentage loaded, average carried load, and ton-mileage for single-unit trucks, truck combinations, and these two types of vehicles combined, when operated as private and as for-hire vehicles. An appreciably larger percentage of the for-hire vehicles are loaded; the loads carried by these vehicles are much heavier; and the average carried loads are increasing at a more rapid rate than for privately operated vehicles. Single-unit trucks transport an important part of the freight moved in privately operated vehicles, but only a minor part of the freight moved by for-hire trucks.

The first part of table 7 gives a detailed comparison of the percentage of vehicle-miles of travel, percentage of vehicles loaded, average carried load, and percentage of total ton-mileage carried by the various types of trucks and truck combinations traveling on main rural roads in 1948 and 1949. Many

interesting comparisons can be made from this table showing the relative importance from a freight-carrying standpoint of different portions of the traffic stream. In 1949, for instance, while panel and pickup trucks traveled almost 32 percent of the vehicle-mileage, they accounted for less than 3 percent of the ton-mileage. The truck-tractor and semitrailer combinations traveled less than 27 percent of the vehicle-mileage, but they carried almost 66 percent of the ton-mileage.

From the columns in table 7 showing the percentage loaded, by types, it can be observed that the percentage of vehicles carrying loads increases directly as the size of the vehicle type, extending from the light panel and pickup trucks that are loaded 36 percent of the time, to the heavy combinations that are loaded over 65 percent of the time.

The right-hand portion of table 7 shows the percentage loaded, average carried load, and percentage of total ton-mileage carried by various types of privately operated trucks and truck combinations compared to those operated for-hire on the main rural roads in 1949. The percentage of travel (vehicle-mileage) by these types is given in table 3. A comparison of vehicle-mileage percentage with ton-mileage

percentage, by operating classes, shows that panel and pickup trucks, privately operated travel over 40 percent of the vehicle-mile while transporting only about 5 percent of freight moved in privately operated vehicles. At the same time, for-hire panels and pickup travel less than 2 percent of the total for-hire vehicle-mileage and carry only 0.2 percent of the total ton-mileage moved by the for-hire vehicles. The heavy-vehicle combinations, privately operated, travel about 15 percent of the total mileage and carry almost 51 percent of the freight moved by privately operated vehicles, while the for-hire combinations travel almost 74 percent of the total vehicle-mileage of all such vehicles and carry over 99 percent of the freight transported by all for-hire trucks and combinations.

Gross Weights Increasing Slightly

Figure 7 shows for the United States as a whole the frequency of gross weights by year from the prewar years (generally 1936 or 1937) to 1949, of 30,000 pounds or more, of 40,000 pounds or more, and of 50,000 pounds or more. The trend of frequency of heavy loads continues upward although the frequency of 50,000-pound weights was slightly less in 1949 than in the previous year. The frequency of these heaviest loads was 12 times greater in 1949 than in the prewar year, the weight of 40,000 pounds or more were 7 times as frequent, and those of 30,000 pounds or more were 3½ times as frequent as in the early years of the surveys. Vehicles weighing 30,000 pounds or more and 40,000 pounds or more appear in greater numbers than ever before, whereas the number of those in the heaviest group declined slightly.

The 1949 gross-weight frequency data by vehicle type and region are presented in table 8. No panels, pickups, or other two-axle, four-tire, single-unit trucks were found in the survey weighing as much as 30,000 pounds or more; there is no entry for these vehicles in table 8, though they are included in the total number of vehicles weighed in computing the frequencies for all trucks and combinations. Heavy gross weights are much more frequent in the Pacific region than in other parts of the country. In this region 99 of each 100 trucks and truck combinations on the main rural highways in 1949, empties included, weighed 50,000 pounds or more. This

Table 7.—Percentage of vehicle-miles of travel, percentage loaded, average carried load, and percentage of total ton-miles carried by various types of trucks and truck combinations on main rural roads in 1949 compared to that in corresponding months of 1948

Vehicle type	Percentage of vehicle-miles of travel		Percentage loaded		Average carried load		Percentage of ton-miles carried		Distribution by type of operation in 1949					
									Percentage loaded		Average carried load		Percentage of ton-miles carried	
	1949	1948	1949	1948	1949	1948	1949	1948	Private	For-hire	Private	For-hire	Private	For-hire
Single-unit trucks:					Tons	Tons					Tons	Tons		
Panel and pickup	31.55	28.90	35.9	36.7	0.64	0.64	2.75	2.60	35.72	48.13	0.63	1.42	5.45	0.1
Other 2-axle, 4 tire	3.46	3.59	49.4	51.9	.78	1.24	.50	.88	49.39	47.75	.74	2.76	.96	.1
Other 2-axle, 6-tire	35.34	38.66	54.5	53.6	3.17	3.10	23.15	24.51	54.40	55.40	3.06	3.82	39.28	7.9
3-axle	1.58	1.70	54.8	55.2	7.23	6.57	2.38	2.35	53.44	58.09	7.11	7.52	3.33	1.1
All single-unit trucks	71.93	72.85	46.1	46.8	2.29	2.33	28.78	30.34	45.30	55.05	2.10	3.97	49.02	9.1
Truck combinations:														
Truck-tractor and semitrailer	26.57	25.35	63.8	66.2	9.95	9.83	65.91	63.09	61.11	68.98	9.39	10.27	47.98	82.1
Truck and trailer	1.50	1.80	63.4	70.2	14.69	13.64	5.31	6.57	63.60	63.24	10.08	17.75	3.00	7.1
All truck combinations	28.07	27.15	65.7	66.5	10.19	10.10	71.22	69.66	61.24	68.67	9.43	10.65	50.98	90.1
All trucks and truck combinations	100.00	100.00	51.6	52.2	5.11	5.02	100.00	100.00	47.63	65.07	3.48	9.16	100.00	100.0

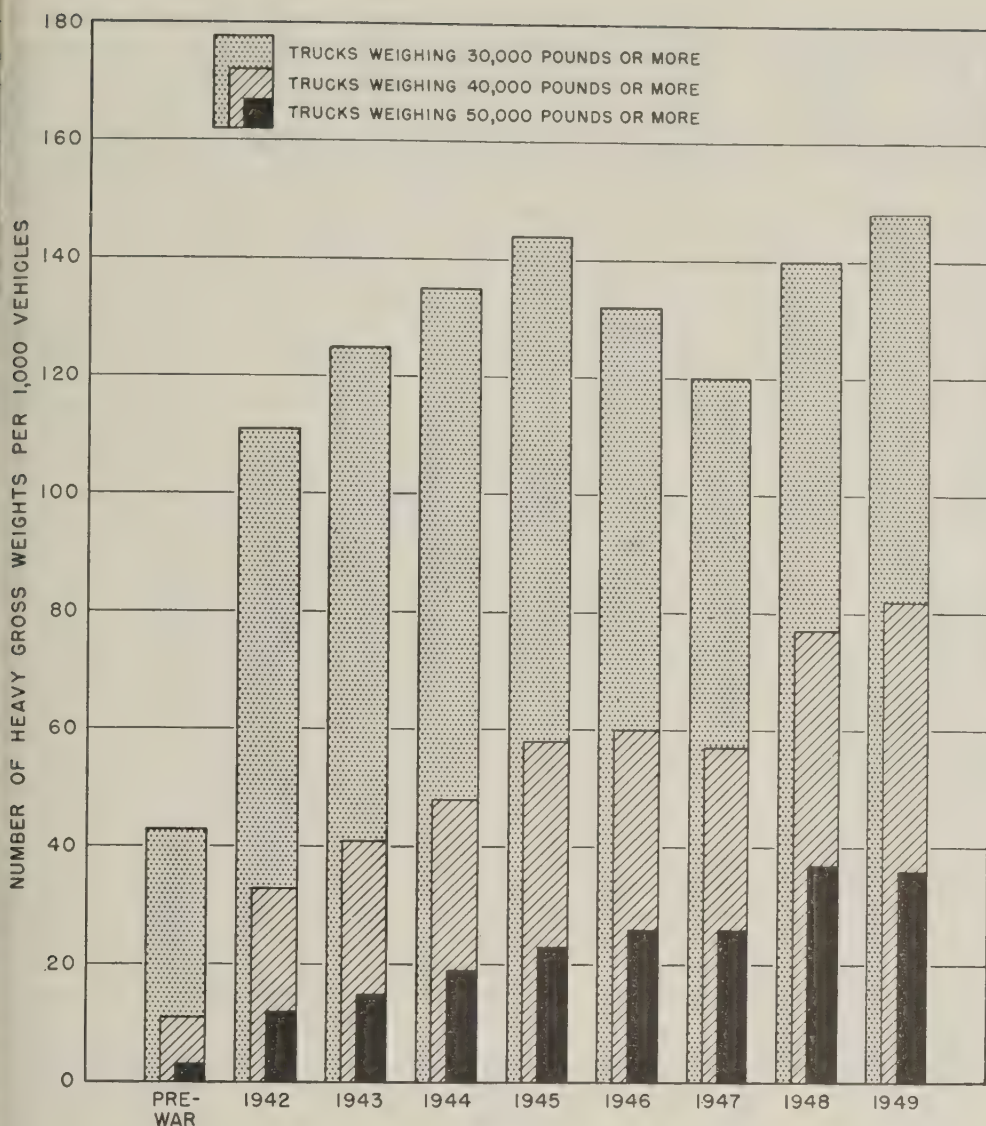


Figure 7.—Number of heavy gross weights per 1,000 trucks and truck combinations (empties included) in the summers of 1942-49 and a prewar year.

frequency is the same as was found in 1948 but slightly lower than the 1946 figure of 104 for each 1,000 in this heavy category. These heavy vehicles are almost entirely of the combination type, approximately 40 percent of all combinations observed, or about 52 percent of the loaded ones, weighing 50,000 pounds or more. In the East South Central region these heavy gross weights were about one-fifteenth as frequent as in the Pacific region, while in the New England, South Atlantic, and West South Central regions the heavy weights were one-fifth as frequent as in the Pacific region.

Frequency of Heavy Axle Loads

Figure 8 shows the frequency of axle loads of 18,000 pounds or more, of 20,000 pounds or more, and of 22,000 pounds or more, by years from the prewar years (1936-37) to 1949. The frequency of heavy axle loads increased year by year from the prewar period through 1948. The frequencies for 1949 are slightly lower than those found in the previous year, yet are higher than in any other previous period and fit very closely the long-time trend from 1942 through 1947. Axle loads in excess of 22,000 pounds increased in frequency from 10 per 1,000 vehicles in the prewar period to 15 per 1,000 vehicles in 1949, an increase of

750 percent. Somewhat lesser increases occurred in the frequencies of axle loads from 18,000 to 20,000 pounds. The decline in heavy axle loads in all the categories from 1948 to 1949, coupled with the decline in frequency of the heaviest gross loads shown in figure 7, may possibly indicate that increased enforcement activity is being reflected in better law observance. One year's reversal in trend is insufficient to warrant conclusions. The 1950 survey results should show whether the trend will continue downward from 1948 or resume the steady upward course followed prior to that year.

Table 9 gives data concerning the number of heavy axle loads per 1,000 loaded and empty trucks and truck combinations of various types on the main rural roads in the summer of 1949. Since no panel or pickup trucks were found with axles weighing 18,000 pounds or more, there is no entry for these in the table, though they are included in figuring the frequencies for all trucks and truck combinations.

Though the greatest frequency of heavy gross weights is in the Pacific region, as shown in table 8, the lowest frequency of heavy axle loads is in this same region. The greatest frequency is in the Middle Atlantic region and

the next greatest in New England. In these two regions the relatively high frequency is attributable mainly to the large number of two-axle truck-tractors pulling one-axle or two-axle semitrailers. The relative infrequency of heavy axles in the Pacific region, in the presence of a large proportion of heavy gross loads, indicates a better distribution of the loads over a larger number of axles.

Loads Above Legal Limits

Table 10⁶ shows the number of trucks and truck combinations of each type, per 1,000 such vehicles counted, empties included, that exceeded the permissible axle, axle-group, or gross-weight legal limits in effect in the individual States in the summer of 1949, and the number per 1,000 that exceeded these limits by various percentages. Loads in excess of the State legal limits were most frequent, as in 1948, in the East North Central region where it was found that 63 of each 1,000 vehicles exceeded a State weight limit. The Middle Atlantic region stood second in frequency of violations, with 59 vehicles out of each 1,000 exceeding a load limit, followed closely by the Mountain region with 58 violations per 1,000 vehicles.

A comparison of the frequency of loads exceeding State legal limits in 1949, shown in table 10, with similar data collected in the previous year, indicates that these excessive loads have decreased in all areas except the Mountain and Pacific regions. In the Mountain region the frequency increased 45 percent, while in the Pacific region the increase was about 9 percent. For the country as a whole, excessive loads in 1949 were slightly less frequent than in 1948 but slightly more than in 1947. No panel or pickup truck was weighed that exceeded any of the State weight regulations and this classification is omitted from the tables although the number of such vehicles counted is included in the calculations.

Recommended Weight Limits

Uniform regulations concerning maximum allowable gross weights, axle weights, and axle-group weights have been adopted as a policy by the American Association of State Highway Officials and recommended to the State governments for adoption.⁷ This policy recommends that no axle shall carry a load in excess of 18,000 pounds and no group of axles shall carry a load in excess of amounts specified in a table of permissible weights based on the distance between the extremes of any group of axles.

In table 11 is shown the number of axles per 1,000 vehicles of various types that exceeded the axle-load limit of 18,000 pounds recommended by the A.A.S.H.O. and the number exceeding these limits by various percentages.

⁶ Tables 10-14 are on pages 96-98.

⁷ Policy concerning maximum dimensions, weights, and speeds of motor vehicles to be operated over the highways of the United States, adopted April 1, 1946, by the American Association of State Highway Officials; published by the Association in 1946.

Table 8.—Heavy gross weights per 1,000 loaded and empty trucks and truck combinations on main rural roads, summer of 1949

Vehicle type ¹	Eastern regions				Central regions					Western regions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
NUMBER PER 1,000 WEIGHING 30,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 6-tire.....	16	19	3	11	(2)	(2)	(2)	2	1	6	(2)	4	5
3-axle.....	286	371	245	309	221	298	212	231	229	206	208	207	253
Average.....	16	22	8	14	6	3	3	3	4	7	14	10	8
Truck combinations:													
Truck-tractor and semitrailer.....	475	595	498	539	521	458	517	434	492	569	644	612	520
Truck and trailer.....	(2)	(3)	(3)	---	789	0	82	53	495	783	722	739	657
Average.....	476	596	498	540	534	457	502	424	492	613	668	647	528
Average, all trucks and truck combinations.....	117	191	130	153	208	87	139	107	144	118	176	147	148
NUMBER PER 1,000 WEIGHING 40,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 6-tire.....	1	1	0	(2)	0	0	(2)	0	(2)	(2)	0	(2)	(2)
3-axle.....	137	157	40	107	34	0	14	112	38	69	12	28	61
Average.....	4	5	1	3	1	0	(2)	1	1	1	1	1	1
Truck combinations:													
Truck-tractor and semitrailer.....	287	390	285	332	262	189	293	221	250	380	481	438	297
Truck and trailer.....	(3)	(3)	(2)	---	512	0	67	31	323	461	523	506	448
Average.....	289	391	285	333	274	189	285	215	252	397	494	456	305
Average, all trucks and truck combinations.....	66	120	71	90	105	36	77	54	73	75	121	97	82
NUMBER PER 1,000 WEIGHING 50,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 6-tire.....	0	0	0	0	0	0	0	0	0	(2)	0	(2)	(2)
3-axle.....	6	15	4	9	21	0	0	0	10	14	2	5	9
Average.....	(2)	1	(2)	(2)	1	0	0	0	(2)	(2)	(2)	(2)	(2)
Truck combinations:													
Truck-tractor and semitrailer.....	69	170	87	122	109	28	124	75	94	243	382	323	127
Truck and trailer.....	0	(2)	(2)	---	455	0	31	10	278	381	470	446	392
Average.....	69	171	87	123	125	28	120	74	100	271	409	356	141
Average, all trucks and truck combinations.....	15	52	21	33	48	6	32	18	29	51	99	75	36

¹ No two-axle, four-tire trucks weighing as much as 30,000 pounds were reported.² Data omitted because of insufficient sample.³ Less than 5 per 10,000.

Table 9.—Heavy axle loads per 1,000 loaded and empty trucks and truck combinations on main rural roads in the summer of 1949

Vehicle type ¹	Eastern regions				Central regions					Western regions			United States average
	New England	Middle Atlantic	South Atlantic	Average	East North Central	East South Central	West North Central	West South Central	Average	Mountain	Pacific	Average	
NUMBER PER 1,000 WEIGHING 18,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 4-tire.....	0	2	2	2	0	0	0	0	0	0	0	0	1
2-axle, 6-tire.....	46	58	23	40	10	18	10	11	12	34	14	24	23
3-axle.....	116	169	55	116	67	33	11	56	48	71	4	23	67
Average.....	27	38	13	24	7	9	5	5	6	15	7	11	13
Truck combinations:													
Truck-tractor and semitrailer.....	471	566	361	462	206	238	179	198	203	252	147	192	290
Truck and trailer.....	0	(2)	0	-----	578	0	50	10	355	188	106	128	210
Average.....	468	567	361	462	223	237	175	193	208	239	135	175	286
Average, all trucks and truck combinations.....	124	195	99	140	89	50	50	51	63	57	37	48	86
NUMBER PER 1,000 WEIGHING 20,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 4-tire.....	0	0	0	0	0	0	0	0	0	0	0	0	0
2-axle, 6-tire.....	27	36	9	23	4	6	2	3	3	18	3	10	11
3-axle.....	40	69	27	48	32	0	0	0	15	58	0	16	28
Average.....	15	22	5	13	3	3	1	1	2	8	1	5	6
Truck combinations:													
Truck-tractor and semitrailer.....	281	341	172	257	60	86	42	72	62	113	28	64	128
Truck and trailer.....	0	(2)	0	-----	211	0	14	0	128	44	8	18	61
Average.....	280	342	172	257	67	86	41	70	64	99	22	52	124
Average, all trucks and truck combinations.....	73	118	46	78	27	18	12	18	20	26	6	16	38
NUMBER PER 1,000 WEIGHING 22,000 POUNDS OR MORE													
Single-unit trucks:													
2-axle, 4-tire.....	0	0	0	0	0	0	0	0	0	0	0	0	0
2-axle, 6-tire.....	16	17	4	11	1	2	1	1	1	9	1	5	1
3-axle.....	0	29	8	17	29	0	0	0	14	24	0	7	11
Average.....	9	11	2	6	1	1	(2)	(2)	1	4	(3)	2	1
Truck combinations:													
Truck-tractor and semitrailer.....	120	193	66	127	19	22	8	24	18	46	5	22	54
Truck and trailer.....	0	0	0	0	91	0	12	0	57	23	4	9	21
Average.....	120	192	66	127	22	22	8	23	20	41	5	19	55
Average, all trucks and truck combinations.....	33	65	18	39	9	5	3	6	6	11	2	6	17

¹ No panel or pick-up trucks with an 18,000-pound axle load were reported.² Less than 5 per 10,000.³ Data omitted because of insufficient sample.

This table emphasizes again the high frequency of heavy axle loads in the Middle Atlantic and New England regions. The number of axles per 1,000 vehicles weighing more than the recommended limits was 175 in the Middle Atlantic and 109 in the New England regions, while only 31 such axles for each 1,000 vehicles were found in the Pacific region. For the United States as a whole axle loads heavier than 18,000 pounds were about 12 percent less frequent in 1949 than in 1948, although almost 14 percent more frequent than in 1947.

Table 12 shows the number of vehicles of various types per 1,000 with an axle-group loaded in excess of the limits recommended by the A.A.S.H.O. and in excess of these limits by various percentages. For the country as a whole, of each 1,000 loaded and empty trucks and truck combinations, 28 had axle-group loads⁸ weighing in excess of the recommended limits, 7 of which exceeded the limits by more than 20 percent. Of each 1,000 combinations weighed, 98 had axle-group loads weighing more than the recommended limits, of which 24 exceeded the limits by more than 20 percent. The frequency of the excessive axle-group loads in 1949 was about 7 percent less than in 1948 and 12 percent above the 1947 frequency.

As might be expected, many vehicles were so loaded that they exceeded more than one recommended weight limit, and some vehicles had more than one axle loaded in excess of the recommended limit. Counting each vehicle only once, regardless of the number of ways in which it exceeded any of the A.A.S.H.O. recommended limits, table 13 was derived to show the number of vehicles per 1,000 of each type, both loaded and empty, that exceeded the limits by various percentages. Those vehicles which exceeded more than one provision of the recommended restrictions were tabulated in the column showing the highest percentage excess only for any item.

In the United States as a whole, 68 vehicles out of every 1,000 were overloaded to some degree, and 19 out of every 1,000 exceeded some one of the provisions by more than 20 percent. The frequency of vehicles exceeding the recommendations by any amount in 1949 was 7 percent less than in 1948 and about 15 percent greater than in 1947.

In considering the data concerning the frequencies of axles or vehicles exceeding the State legal limits and the A.A.S.H.O. recommendations, especially the frequencies in the Middle Atlantic and New England regions, the fact should be recognized that higher limits generally are permissible under the State laws in this area than are recommended by the Association. Axles exceeding the recommended limits by 25 percent may be within

⁸ The frequency of 28 vehicles of each 1,000 weighed that exceeded the A.A.S.H.O. axle-group recommendation, found in the final analysis of these data as shown in table 12, is slightly larger than the frequency of 2.56 percent (or 26 per 1,000) found in the preliminary analysis reported to the Subcommittee of the Senate Committee on Interstate and Foreign Commerce.

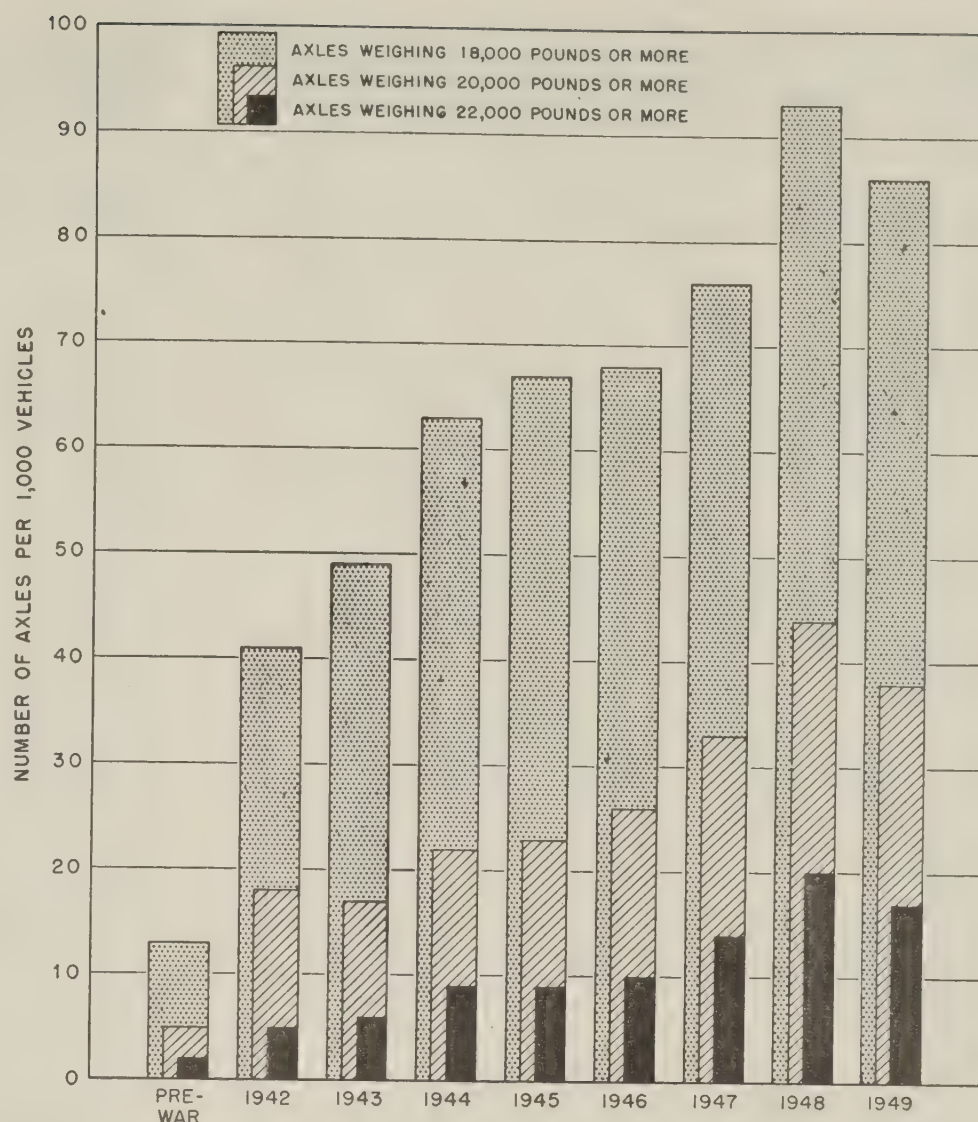


Figure 8.—Number of heavy axle loads per 1,000 trucks and truck combinations (empties included) in the summers of 1942-49 and a prewar year.

the legal limits of certain States, particularly in these two regions. Some States have no axle limits or axle-group limits in their motor-vehicle restrictions, a fact that complicates direct comparison of excess weights based on law and those based on the recommendations. Comparison of the frequency data given in table 13 with those in table 10 shows that from one-third to one-half of the vehicles exceeding one or more of the Association recommendations actually exceeded a State legal limit.

For-Hire Vehicles More Frequently Overloaded

The first part of table 14 shows the number of privately operated trucks and truck combinations and those operated for-hire, for each 1,000 such loaded and empty vehicles, on main rural roads of the United States, that exceeded some State legal weight limit in 1949. A comparison of the frequency of the excessively loaded vehicles in the two operation classifications shows, in a striking manner, that type by type, the for-hire vehicles generally are more frequently overloaded than are the privately operated ones.

For instance, 6 of each 1,000 private single-unit trucks exceeded a State weight limit while 27 of each 1,000 for-hire trucks exceeded the same limits. Likewise, 146 of each 1,000 private truck combinations exceeded State weight limits, while 168 of each 1,000 for-hire combinations exceeded the same limits.

Of each 1,000 vehicles, the frequencies of all private and all for-hire trucks and truck combinations exceeding the State limits were 26 and 131, respectively. In other words, there were five times as many excess loads among the for-hire vehicles as among the privately operated ones. This is as would be expected, because the heavier vehicles are operated more frequently for-hire and the lighter ones for private transportation.

The following parts of table 14 show frequencies of private and for-hire trucks and truck combinations exceeding the A.A.S.H.O. recommended limits for axle loads, for maximum axle-group loads, or for any of the recommended maximum loads. This table shows, in general, that the relation of the frequency of overload of privately operated and of for-hire vehicles is the same when based on A.A.S.H.O. recommendations or on State legal limits.

Table 10.—Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded the permissible axle, axle-group, or gross-weight legal limits in effect in the States by various percentages (maximum) of overload, summer of 1949

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over- loaded	Number per 1,000 overloaded more than—				
		5 per- cent	10 per- cent	20 per- cent	30 per- cent	50 per- cent
New England:						
2-axle, 4-tire	15	12	7	4	1	(1)
2-axle, 6-tire	85	76	57	11	6	
3-axle	10	8	5	2	1	(1)
Average, single-unit trucks	91	53	34	12	5	1
Truck-tractor and semitrailer						
Truck and trailer						
Average, truck combinations	91	53	34	12	5	1
Average, all trucks and combinations	28	18	11	4	2	(1)
Middle Atlantic:						
2-axle, 4-tire	21	13	9	3	1	(1)
2-axle, 6-tire	209	178	115	66	28	
3-axle	18	13	9	4	1	(1)
Average, single-unit trucks	147	102	73	38	24	6
Truck-tractor and semitrailer	(2)	(2)	(2)			
Truck and trailer	149	104	75	38	24	6
Average, truck combinations						
Average, all trucks and combinations	59	42	30	15	8	2
South Atlantic:						
2-axle, 4-tire	1	1	1	1		
2-axle, 6-tire	14	10	7	2	1	(1)
3-axle	41	27	11	8		
Average, single-unit trucks	8	6	4	1	(1)	(1)
Truck-tractor and semitrailer	169	110	70	24	11	1
Truck and trailer						
Average, truck combinations	169	110	70	24	11	1
Average, all trucks and combinations	53	35	22	7	7	(1)
East North Central:						
2-axle, 4-tire	7	5	3	1	(1)	
2-axle, 6-tire	72	69	66	43	29	20
3-axle	5	4	3	2	1	(1)
Average, single-unit trucks	156	106	65	28	13	2
Truck-tractor and semitrailer	316	226	117	98	40	25
Truck and trailer	163	112	70	31	14	3
Average, truck combinations						
Average, all trucks and combinations	63	43	27	13	6	1
East South Central:						
2-axle, 4-tire	9	9	4	4	4	
2-axle, 6-tire	13	7	4	2	1	
3-axle	66	43	11			
Average, single-unit trucks	7	4	2	1	1	
Truck-tractor and semitrailer	162	118	81	26	9	1
Truck and trailer						
Average, truck combinations	162	118	81	26	9	1
Average, all trucks and combinations	36	25	17	6	2	(1)
West North Central:						
2-axle, 4-tire	7	2	1	1		
2-axle, 6-tire	56	37	24	8		
3-axle	5	2	1	1		
Average, single-unit trucks	179	123	76	29	12	1
Truck-tractor and semitrailer	20	16	8	6		
Truck and trailer	173	119	74	28	12	1
Average, truck combinations						
Average, all trucks and combinations	46	30	19	8	3	(1)
West South Central:						
2-axle, 4-tire	10	7	4	1		
2-axle, 6-tire						
3-axle	4	3	2	(1)		
Average, single-unit trucks	153	115	76	31	11	5
Truck-tractor and semitrailer	10	10				
Truck and trailer	149	112	74	30	11	5
Average, truck combinations						
Average, all trucks and combinations	42	31	21	8	3	1
Mountain:						
2-axle, 4-tire	2	2	2	2	2	
2-axle, 6-tire	34	31	19	11	7	(-)
3-axle	63	55	48	38	34	
Average, single-unit trucks	15	13	8	5	4	(1)
Truck-tractor and semitrailer	215	167	120	64	27	5
Truck and trailer	233	179	121	69	25	15
Average, truck combinations	218	169	120	65	27	7
Average, all trucks and combinations	58	46	32	18	9	1
Pacific:						
2-axle, 4-tire	6	4	2	1	1	1
2-axle, 6-tire	18	7	1	(1)		
3-axle	4	2	1	(1)	(1)	(1)
Average, single-unit trucks	116	63	36	9	3	(1)
Truck-tractor and semitrailer	171	50	16	2	(1)	
Truck and trailer	133	59	30	7	2	(1)
Average, truck combinations						
Average, all trucks and combinations	49	22	11	2	1	(1)
United States average:						
2-axle, 4-tire	1	1	1	(1)	(1)	
2-axle, 6-tire	13	9	6	2	1	(1)
3-axle	75	61	42	24	13	4
Average, single-unit trucks	8	6	4	2	1	(1)
Truck-tractor and semitrailer	158	109	71	29	13	3
Truck and trailer	193	107	70	33	12	8
Average, truck combinations	160	109	71	29	13	3
Average, all trucks and combinations	51	35	23	10	4	1
Average, 1948	55	38	26	12	6	1
Average, 1947	46	34	23	10	4	1

¹ Less than 5 per 10,000.

² Data omitted because of insufficient sample.

Table 11.—Number of axles, per 1,000 loaded and empty trucks and truck combinations, that exceeded the permissible axle load limit of 18,000 pounds recommended by the A.A.S.H.O. various percentages of overload in the summer of 1949

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over- loaded	Number per 1,000 overloaded more than—				
		5 per- cent	10 per- cent	20 per- cent	30 per- cent	50 per- cent
New England:						
2-axle, 4-tire	44	35	30	19	11	3
2-axle, 6-tire	91	46	33			
3-axle	26	20	17	10	6	2
Average, single-unit trucks	403	337	259	118	44	4
Truck-tractor and semitrailer	(1)	(1)	(1)			
Truck and trailer	408	343	261	117	44	4
Average, truck combinations						
Average, all trucks and combinations	109	90	70	33	14	2
Middle Atlantic:						
2-axle, 4-tire	1	1				
2-axle, 6-tire	54	47	40	21	9	2
3-axle	175	129	70	35	21	7
Average, single-unit trucks	36	30	24	13	6	1
Truck-tractor and semitrailer	480	384	312	177	89	24
Truck and trailer	(1)	(1)	(1)			
Average, truck combinations	481	385	313	177	89	24
Average, all trucks and combinations						
Average, all trucks and combinations	175	141	115	64	32	8
South Atlantic:						
2-axle, 4-tire	1	1	1			
2-axle, 6-tire	17	13	9	3	2	(2)
3-axle	55	41	27	8		
Average, single-unit trucks	10	7	5	2	1	(2)
Truck-tractor and semitrailer	299	229	160	62	21	3
Truck and trailer						
Average, truck combinations	299	229	160	62	21	3
Average, all trucks and combinations	90	68	48	19	7	1
East North Central:						
2-axle, 4-tire						
2-axle, 6-tire	7	5	3	1		
3-axle	34	34	31	28	20	
Average, single-unit trucks	5	3	2	1	1	
Truck-tractor and semitrailer	165	104	60	22	8	1
Truck and trailer	406	247	151	63	17	
Average, truck combinations	176	111	64	24	8	1
Average, all trucks and combinations	67	42	25	9	4	(2)
East South Central:						
2-axle, 4-tire	9	9	4	4	4	
2-axle, 6-tire	13	7	4	2	1	
3-axle	33	11				
Average, single-unit trucks	7	4	2	1	1	
Truck-tractor and semitrailer	191	131	79	22	7	1
Truck and trailer						
Average, truck combinations	191	131	79	22	7	1
Average, all trucks and combinations	41	28	16	5	2	(2)
West North Central:						
2-axle, 4-tire						
2-axle, 6-tire	7	2	1	(2)		
3-axle	21	10	2	2		
Average, single-unit trucks	4	1	1	(2)		
Truck-tractor and semitrailer	168	94	51	14	5	1
Truck and trailer	9	9	5	4		
Average, truck combinations	162	91	49	14	5	1
Average, all trucks and combinations	42	23	13	3	1	(2)
West South Central:						
2-axle, 4-tire	10	7	4	1		
2-axle, 6-tire						
3-axle						
Average, single-unit trucks	4	3	2	(2)		
Truck-tractor and semitrailer	180	122	73	27	11	2
Truck and trailer	10	10				
Average, truck combinations	175	119	71	26	11	2
Average, all trucks and combinations	49	33	20	7	3	1
Mountain:						
2-axle, 4-tire	2	2	2	2	2	
2-axle, 6-tire	33	31	19	11	7	(2)
3-axle	67	67	67	27	13	
Average, single-unit trucks	14	14	9	5	3	(2)
Truck-tractor and semitrailer	216	158	112	51	21	4
Truck and trailer	132	75	39	15	7	2
Average, truck combinations	201	143	99	44	18	4
Average, all trucks and combinations	54	41	28	13	6	1
Pacific:						
2-axle, 4-tire						
2-axle, 6-tire	6	4	2	1	1	1
3-axle	2					
Average, single-unit trucks	3	2	1	(2)	(2)	(2)
Truck-tractor and semitrailer	70	37	16	3	1	(2)
Truck and trailer	113	40	12	2	(2)	
Average, truck combinations	83	38	14	3	1	(2)
Average, all trucks and combinations	31	15	6	1	(2)	(2)
United States average:						
2-axle, 4-tire	1	1	1	(2)	(2)	
2-axle, 6-tire	19	15	11	5	3	(2)
3-axle	57	43	28	14	8	1
Average, single-unit trucks	11	8	6	3	2	(2)
Truck-tractor and semitrailer	242	175	122	55	24	5
Truck and trailer	168	92	50	17	4	(2)
Average, truck combinations	238	171	118	53	23	5
Average, all trucks and combinations	75	54	37	17	8	1
Average, 1948	85	63	45	23	11	2
Average, 1947	66	49	33	15	7	1

¹ Data omitted because of insufficient sample.

² Less than 5 per 10,000.

Table 12.—Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded the permissible axle-group loads recommended by the A.A.S.H.O. by various percentages of overload in the summer of 1949

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over- loaded	Number per 1,000 overloaded more than—				
		5 per- cent	10 per- cent	20 per- cent	30 per- cent	50 per- cent
New England:						
2-axle, 4-tire	1	1	1	(1)		
2-axle, 6-tire	106	81	48	24	6	
3-axle	3	3	2	1	(1)	
Average, single-unit trucks	68	42	24	10	4	(1)
Truck-tractor and semitrailer	(2)	(2)	(2)	(2)	(2)	
Truck and trailer	71	45	27	14	8	(1)
Average, truck combinations	18	12	7	4	2	(1)
Average, all trucks and combinations						
Middle Atlantic:						
2-axle, 4-tire	1					
2-axle, 6-tire	157	129	112	45	14	7
3-axle	5	4	3	1	(1)	(1)
Average, single-unit trucks	142	102	73	41	25	5
Truck-tractor and semitrailer	(2)	(2)	(2)			
Truck and trailer	144	104	75	41	25	5
Average, truck combinations	49	35	26	14	8	2
Average, all trucks and combinations						
South Atlantic:						
2-axle, 4-tire						
2-axle, 6-tire	62	34	21	14	8	
3-axle	1	1	(1)	(1)	(1)	
Average, single-unit trucks	54	39	29	16	9	1
Truck-tractor and semitrailer						
Truck and trailer	54	39	29	16	9	1
Average, truck combinations	16	12	8	4	3	(1)
Average, all trucks and combinations						
East North Central:						
2-axle, 4-tire						
2-axle, 6-tire	48	35	35	29	29	10
3-axle	1	1	1	1	1	(1)
Average, single-unit trucks	98	75	50	25	11	3
Truck-tractor and semitrailer	425	407	374	293	191	56
Truck and trailer	113	90	65	37	19	6
Average, truck combinations	42	33	24	14	8	2
Average, all trucks and combinations						
East South Central:						
2-axle, 4-tire						
2-axle, 6-tire	11					
3-axle	(1)					
Average, single-unit trucks	25	15	9	2	1	(1)
Truck-tractor and semitrailer						
Truck and trailer	25	15	9	2	1	(1)
Average, truck combinations	5	3	2	(1)	(1)	(1)
Average, all trucks and combinations						
West North Central:						
2-axle, 4-tire						
2-axle, 6-tire	15	8	8			
3-axle	(1)	(1)	(1)			
Average, single-unit trucks	83	58	36	11	4	(1)
Truck-tractor and semitrailer	16	6	6	2		
Truck and trailer	81	56	35	11	4	(1)
Average, truck combinations	20	14	9	3	1	(1)
Average, all trucks and combinations						
West South Central:						
2-axle, 4-tire						
2-axle, 6-tire						
3-axle						
Average, single-unit trucks	52	36	22	11	6	2
Truck-tractor and semitrailer	10	10	10	10	10	
Truck and trailer	51	35	22	11	6	2
Average, truck combinations	13	9	6	3	2	1
Average, all trucks and combinations						
Mountain:						
2-axle, 4-tire	(1)	(1)	(1)			
2-axle, 6-tire	53	50	38	33	15	
3-axle	1	1	1	1	(1)	
Average, single-unit trucks	160	122	92	43	19	3
Truck-tractor and semitrailer	246	185	126	47	29	12
Truck and trailer	176	134	98	44	21	5
Average, truck combinations	38	29	22	10	4	1
Average, all trucks and combinations						
Pacific:						
2-axle, 4-tire						
2-axle, 6-tire	11	5				
3-axle	1	(1)				
Average, single-unit trucks	143	111	71	22	5	(1)
Truck-tractor and semitrailer	258	178	74	5	(1)	
Truck and trailer	179	132	72	17	3	(1)
Average, truck combinations	64	46	25	6	1	(1)
Average, all trucks and combinations						
United States average:						
2-axle, 4-tire	(1)	(1)	(1)	(1)		
2-axle, 6-tire	58	43	34	19	10	3
3-axle	1	1	1	(1)	(1)	(1)
Average, single-unit trucks	89	65	44	21	10	2
Truck-tractor and semitrailer	260	207	140	72	46	13
Truck and trailer	98	73	49	24	12	3
Average, truck combinations	28	21	14	7	3	1
Average, all trucks and combinations						
Average, 1948	30	22	16	7	3	1
Average, 1947	25	19	12	5	2	1

¹ Less than 5 per 10,000.

² Data omitted because of insufficient sample.

Table 13.—Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded any of the permissible load limits recommended by the A.A.S.H.O. by various percentages (maximum) of overload in the summer of 1949

Region and type of vehicle (panel and pickup trucks excluded)	Number per 1,000 over- loaded	Number per 1,000 overloaded more than—				
		5 per- cent	10 per- cent	20 per- cent	30 per- cent	50 per- cent
New England:						
2-axle, 4-tire						
2-axle, 6-tire	44	36	30	19	11	3
3-axle	119	86	57	24	6	
Average, single-unit trucks	26	21	17	11	6	2
Truck-tractor and semitrailer	288	250	203	108	45	4
Truck and trailer	(1)	(1)	(1)	(1)	(1)	
Average, truck combinations	290	252	206	111	48	4
Average, all trucks and combinations	84	71	58	33	15	2
Middle Atlantic:						
2-axle, 4-tire	1	1				
2-axle, 6-tire	54	47	40	21	9	2
3-axle	181	149	112	53	21	7
Average, single-unit trucks	36	31	26	13	6	1
Truck-tractor and semitrailer	345	284	244	153	85	26
Truck and trailer	(1)	(1)	(1)	(1)		
Average, truck combinations	346	285	245	153	85	26
Average, all trucks and combinations	133	111	95	57	31	9
South Atlantic:						
2-axle, 4-tire	1	1	1			
2-axle, 6-tire	17	13	9	3	2	(2)
3-axle	66	37	24	14	8	
Average, single-unit trucks	10	7	5	2	1	(2)
Truck-tractor and semitrailer	229	182	138	64	26	4
Truck and trailer						
Average, truck combinations	229	182	138	64	26	4
Average, all trucks and combinations	71	55	42	19	8	1
East North Central:						
2-axle, 4-tire	7	5	3	1		
2-axle, 6-tire	56	43	43	38	29	10
3-axle	5	4	3	1	1	(2)
Average, single-unit trucks	180	133	86	39	18	3
Truck-tractor and semitrailer	425	414	381	293	191	56
Truck and trailer	191	146	100	51	26	6
Average, truck combinations	73	56	38	19	10	2
Average, all trucks and combinations						
East South Central:						
2-axle, 4-tire	9	9	4	4	4	
2-axle, 6-tire	13	7	4	2	1	
3-axle	33	11				
Average, single-unit trucks	7	4	2	1	1	
Truck-tractor and semitrailer	151	111	74	22	8	1
Truck and trailer						
Average, truck combinations	151	111	74	22	8	1
Average, all trucks and combinations	35	24	15	5	2	(2)
West North Central:						
2-axle, 4-tire	7	2	1	1		
2-axle, 6-tire	36	17	10	2		
3-axle	4	1	1	1		
Average, single-unit trucks	172	112	65	20	8	1
Truck-tractor and semitrailer	16	8	8	6		
Truck and trailer	167	108	63	20	8	1
Average, truck combinations	44	27	16	6	2	(2)
Average, all trucks and combinations						
West South Central:						
2-axle, 4-tire	10	7	4	1		
2-axle, 6-tire						
3-axle	4	3	2	(2)		
Average, single-unit trucks	149	113	73	30	12	3
Truck-tractor and semitrailer	10	10	10	10	10	
Truck and trailer	145	110	72	29	12	3
Average, truck combinations	41	31	20	8	3	1
Average, all trucks and combinations						
Mountain:						
2-axle, 4-tire	2	2	2	2	2	
2-axle, 6-tire	34	31	19	11	7	(2)
3-axle	63	60	48	34	24	
Average, single-unit trucks	15	13	8	5	3	(2)
Truck-tractor and semitrailer	233	185	139	74	35	6
Truck and trailer	258	198	136	55	29	15
Average, truck combinations	238	187	138	71	34	8
Average, all trucks and combinations	62	50	36	19	10	2
Pacific:						
2-axle, 4-tire	6	4	2	1	1	1
2-axle, 6-tire	13	5	(2)			
3-axle	4	2	1	(2)	(2)	(2)
Average, single-unit trucks	166	127	80	22	6	1
Truck-tractor and semitrailer	299	212	83	7	(2)	
Truck and trailer	207	153	81	17	4	1
Average, truck combinations	75	55	29	6	1	(2)
Average, all trucks and combinations						
United States average:						
2-axle, 4-tire	1	1	1	(2)	(2)	
2-axle, 6-tire	19	15	11	6	3	(2)
3-axle	68	50	38	22	12	3
Average, single-unit truck	11	9	6	3	2	(2)
Truck-tractor and semitrailer	210	162	119	58	28	6
Truck and trailer	281	227	148	75	46	14
Average, truck combinations	214	165	121	59	29	6
Average, all trucks and combinations	68	53	38	19	10	2
Average, 1948	73	56	42	23	11	3
Average, 1947	59	45	32	15	7	1

¹ Data omitted because of insufficient sample.

² Less than 5 per 10,000.

Table 14.—Number of trucks and truck combinations per 1,000 loaded and empty vehicles, in private and in for-hire operation, that exceeded various load limits by various percentages of overload in the summer of 1949 (U. S. average)

Type of vehicle	Private operation						For-hire operation					
	Number per 1,000 overloaded	Number per 1,000 overloaded more than—					Number per 1,000 overloaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent		5 percent	10 percent	20 percent	30 percent	50 percent
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING PERMISSIBLE AXLE, AXLE-GROUP, OR GROSS-WEIGHT LEGAL LIMITS OF THE SEVERAL STATES												
2-axle, 4-tire.....	1	1	1	1	(1)	-----	23	16	10	6	3	(1)
2-axle, 6-tire.....	11	7	5	2	1	-----	23	16	10	6	3	(1)
3-axle.....	65	53	39	24	14	5	99	82	51	27	10	-----
Average, single-unit trucks.....	6	4	3	1	1	(1)	27	20	12	7	3	(1)
Truck-tractor and semitrailer.....	148	103	70	29	12	3	164	112	71	29	14	3
Truck and trailer.....	111	61	42	25	20	15	247	140	88	38	6	3
Average, truck combinations.....	146	101	69	29	12	4	168	114	72	29	14	3
Average, all trucks and combinations.....	26	18	13	5	3	1	131	89	56	23	11	2
NUMBER OF AXLES PER 1,000 TRUCKS AND TRUCK COMBINATIONS EXCEEDING THE 18,000-POUND LIMIT RECOMMENDED BY THE A. A. S. H. O.												
2-axle, 4-tire.....	1	1	1	(1)	(1)	-----	12	12	-----	-----	-----	-----
2-axle, 6-tire.....	17	12	9	4	2	(1)	36	29	23	14	6	2
3-axle.....	40	29	20	9	5	-----	97	76	47	27	15	4
Average, single-unit trucks.....	9	6	5	2	1	(1)	38	31	23	14	6	2
Truck-tractor and semitrailer.....	222	159	110	45	18	4	255	186	130	61	28	6
Truck and trailer.....	136	82	50	20	6	1	190	97	50	14	3	-----
Average, truck combinations.....	217	155	107	44	17	4	251	181	126	58	27	6
Average, all trucks and combinations.....	39	28	20	8	3	1	195	141	99	46	21	5
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING THE MAXIMUM AXLE-GROUP LOADS RECOMMENDED BY THE A. A. S. H. O.												
2-axle, 6-tire.....	(1)	(1)	(1)	(1)	-----	-----	1	(1)	(1)	-----	-----	-----
3-axle.....	43	28	24	14	9	3	92	77	60	28	12	4
Average, single-unit trucks.....	1	(1)	(1)	(1)	(1)	(1)	8	6	5	2	1	(1)
Truck-tractor and semitrailer.....	71	54	36	18	9	2	102	74	50	23	11	3
Truck and trailer.....	135	113	89	54	45	20	341	270	175	87	50	11
Average, truck combinations.....	74	57	39	20	11	3	115	85	57	26	13	3
Average, all trucks and combinations.....	12	8	6	3	2	(1)	87	64	43	20	10	2
NUMBER OF TRUCKS AND TRUCK COMBINATIONS PER 1,000 EXCEEDING ANY OF THE MAXIMUM MOTOR-VEHICLE LOADS RECOMMENDED BY THE A. A. S. H. O.												
2-axle, 4-tire.....	1	1	1	(1)	(1)	-----	12	12	-----	-----	-----	-----
2-axle, 6-tire.....	16	12	9	4	2	(1)	36	29	23	16	6	2
3-axle.....	53	36	25	14	9	3	99	80	63	36	18	4
Average, single-unit trucks.....	8	6	5	2	1	(1)	38	31	24	16	6	2
Truck-tractor and semitrailer.....	185	142	104	50	21	5	228	177	129	64	31	7
Truck and trailer.....	140	121	95	51	41	17	372	296	182	90	49	11
Average, truck combinations.....	183	141	104	50	22	6	236	183	132	65	32	7
Average, all trucks and combinations.....	34	26	19	9	4	1	184	143	103	52	25	6

¹ Less than 5 per 10,000.

Report of Trends in Motor-Vehicle Travel Discontinued

For several years past, PUBLIC ROADS has annually carried a companion article, *Trends in motor-vehicle travel*, which provided estimates of total urban and rural travel and average unit travel and fuel consumption of each of the major classes of motor vehicles.

In making these estimates it has been necessary to predicate the estimates of a given year on the sequence of values obtained for previous years, with the 1936-37 period of the comprehensive State-wide traffic surveys as a base. As this base period has become more and

more remote the hazards of the procedure have multiplied.¹

The interval of nearly 15 years and the changes in circumstances affecting travel are so great that the estimates can no longer be published with confidence. It is hoped that they can be resumed when the States have accumulated a sufficient body of current basic data.

¹ A fuller explanation will be found in *Trends in motor-vehicle travel*, 1947, PUBLIC ROADS, vol. 25, No. 3, Mar. 1949, p. 160.

(Continued from page 104)

described here is applicable to such hydraulic materials as pozzolanic, slag, and natural cements which cannot be analyzed accurately by the tentative method for portland cements.

A further application of this method will be for limestone or other calcareous materials even though certain types may be completely soluble in mineral acid. By using J. Lawrence Smith fusion on such material the eventual calcium in solution would be the same as that obtained for the siliceous samples. Thus, no previous knowledge of the calcium content of the sample would be required and the same correction curves would be applicable.

Flame-Photometer Determination of Sodium and Potassium in Soils and Other Siliceous Materials

THE PHYSICAL
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GRAVIMETRIC METHODS for determining the alkalis—sodium, lithium, and potassium—are long and tedious. The lengthy operations required may introduce serious errors unless meticulous care is observed throughout the entire procedure. For this reason, there has long been much effort directed toward developing an alternate procedure for the determination of these elements. This has been accomplished by the recent developments in flame photometry. Successful and rapid flame photometric methods for the determination of sodium and potassium in such complex materials as whole blood, serum, urine, fertilizers, portland cements (1, 4, 7),¹ plant tissues (10, 11), soil extracts, and cation-exchange capacity of soils (8, 9), have been described elsewhere.

The fundamental basis of flame photometry is the long-known fact that all elements, when heated to a sufficiently high temperature, will emit characteristic light waves of definite wave lengths. The intensity of these emissions varies directly with the quantity of the element present. The temperature necessary to cause the emissions for the various elements ranges from the extremely high temperature which may be obtained with an electric arc to the comparatively low temperature of a gas flame. The flame photometer is applicable to those elements which emit radiation at the temperature of an acetylene or propane flame. Essentially, it is an instrument by which the desired element is introduced into a gas flame under carefully controlled conditions, and the characteristic wavelength of the element is isolated and its intensity is measured photoelectrically.

The alkali metals—lithium, sodium, and potassium—emit characteristic radiations at the temperature of the propane flame and a gas is generally used for the determination of these elements. The flame photometer is also applicable to the determination of calcium, strontium, barium, magnesium, manganese, and chromium, provided a higher temperature flame, such as that of acetylene, is used.

¹Italic numbers in parentheses refer to the bibliographic reference list on page 104.

This article presents a method for using a flame photometer to determine the alkalis—sodium and potassium oxides—in soil and other siliceous material which cannot easily be decomposed by mineral acids. The method is much more rapid than existing gravimetric procedures, and yields results which are equally accurate.

The sample is decomposed by fusion and the melt is leached with hot water in order to bring the alkalis into solution as chlorides. The concentration of alkalis in the resulting solution is then determined by means of a flame photometer, using the direct-intensity method.

A wide variety of materials can be analyzed by the method, including soils, sands, rocks, various minerals, ceramic clays, fly ash, and pozzolanic, slag, and natural cements. The method is also applicable to the determination of the alkalis in limestones and other calcareous materials.

Summary

This article describes a method for using the flame photometer to determine sodium and potassium in various siliceous materials which cannot easily be decomposed by acids. These include such materials as soils, sands, rocks, various minerals, ceramic clays, fly ash, pozzolanic cement, natural cement, and slag cement. The alkalis are brought into solution by the J. Lawrence Smith fusion method with calcium carbonate, and the melt leached with hot water as is customary. The concentrations of the sodium and potassium oxides in the resulting solution are then determined with a flame photometer, using the direct-intensity procedure. Tests show that calcium is the only interfering ion present. By careful quantitative control of the reagents and control of the amount of washings, concentration of the calcium ion can be held substantially constant at 1,700 parts per million as calcium oxide. Correction can then be made for the effect of this constituent by the use of correction curves. This makes possible the calibration against standard solutions containing only sodium and potassium chlorides, which is advantageous

since such solutions are used in a large number of other analyses.

In addition to soils, sands, various minerals, ceramic clays, fly ash, and similar siliceous materials, the flame-photometer method is applicable to the determination of the alkalis in the nonportland type cements such as pozzolanic, slag, and natural cements. While actual tests were not made, the method is indicated as also applicable to limestone and other calcareous materials. The advantage of the method for this type of material is that a neutral solution of a definite concentration of calcium oxide is obtained regardless of the calcium content of the limestone or calcareous material being analyzed.

Comparisons of the results obtained with the flame-photometer method and the results of gravimetric methods show the average differences in percentage to be less than 0.1 when 0.5-gram samples are used. This is of the same order as differences between two gravimetric results on the same sample. The time saved by the flame-photometer method is considerable. Comparative records show that for the same number of analyses only one-fourth the time is required for the flame-photometer method (including the time for calibration) as is required by the usual gravimetric procedure.

Many features of the given flame-photometer method follow well-established procedures. However, the quantitative evaluation of the interferences from other elements and the technique of the detailed operations as given in this article should be of considerable value to those engaged in analyzing such materials or to those who may be seeking further applications of the flame photometer.

Direct-Intensity Procedure

The instrument used in this study was a model 52A Perkin-Elmer flame photometer, which has been described in a number of publications (1, 7). This flame photometer can be used in either of two ways, both of which require careful calibration against standard solutions having a range of concentrations of the desired element overlapping that to be expected in the unknown samples.

These two procedures are known as the internal-standard method and the direct-intensity method.

In the internal-standard method, the emitted light-intensity ratio of the element sought and another element added in known amount (the internal standard) is measured. This is done by amplifying the photoelectric current resulting from the unknown until it equals that from the internal standard, the amount of amplification required being indicated by the reading of the gain-control dial. A basic requirement of the internal-standard method is that the element chosen as the internal standard be absent from the sample to be analyzed. The flame photometer used in this work is so equipped as to require the use of a lithium salt exclusively as the internal standard. However, this element is often present in materials of mineral origin (5, page 517) or highly sodic rocks (12). Thus, in analyzing a wide variety of siliceous materials, the use of the internal-standard method is not desirable.

In the direct-intensity method, a measure of the absolute light-intensity of the element sought is obtained directly by the meter reading and there is no interference from lithium when present.

Method of Analysis

The method described in this article is directly concerned with those materials which are not easily or completely decomposed by mineral acids, and thus require fusion or special digestion in order to bring the alkalis completely into solution.

The familiar J. L. Smith method of fusion with calcium carbonate, as described by Hillebrand and Lundell (5, page 787), was chosen, since its use limits the metals which go into solution. After the fusion the melt is extracted with water in the usual manner and the resulting solution is used for the determinations of the alkalis by means of the flame photometer. The adjustment and calibration of the apparatus follow closely the directions given in the tentative method of test for sodium oxide and potassium oxide in portland cement by flame photometry of the American Society for Testing Materials (1), the chief differences being that the standard solutions used in this method contain only sodium and potassium chloride, and the zero adjustment is made with distilled water.

By careful control of the weights of the sample and the reagents, and of the volume of wash water used, it was found that the amount of calcium in solution could be held substantially constant, and thus the results could be corrected for any interference resulting from this element.

In order to present a complete picture, the method of test, including the calibration of the instrument, the determination of the correction curve, and the preparation of the sample, is given here in detailed step-by-step procedure.

1. Reagents

(a) Calcium carbonate: A.C.S. "low-alkali" CaCO_3 , limited to 0.02 percent total alkalis as sulfate.

(b) Sodium chloride: A.C.S. NaCl with a

maximum limit of 0.01 percent potassium.

(c) Potassium chloride: A.C.S. KCl with a maximum limit of 0.02 percent sodium.

(d) Ammonium chloride: Reagent grade A.C.S. NH_4Cl .

(e) Brom-thymol blue indicator: 0.04 percent solution in water.

(f) Water: Distilled water.

2. Solutions

(a) *Sodium-potassium chloride stock solution.*—Prepare a solution containing 1.8858 gm. of NaCl and 1.5830 gm. of KCl (previously dried at 105°C . for several hours) dissolved in water and diluted to 1 liter in a volumetric flask. This solution contains the equivalent of 1,000 p.p.m. (parts per million) each of Na_2O and K_2O .

(b) *Calcium chloride stock solution.*—Prepare a solution containing 6.068 gm. of CaCO_3 per liter as follows: Weigh the CaCO_3 into a large beaker. Add sufficient water to form a slurry and then add concentrated HCl cautiously until the CaCO_3 is dissolved. Avoid any excess of HCl by adding the acid drop by drop with vigorous stirring until the solution just clears. Cool the solution to room temperature and filter into a 1,000-ml. volumetric flask. Dilute to the mark and mix thoroughly. This solution contains the equivalent of 3,400 p.p.m. of CaO .

(c) *Standard sodium-potassium chloride solutions.*—Using the NaCl-KCl stock solution, prepare standard solutions containing the equivalent of 5, 20, 40, 60, 80, and 100 p.p.m. each of Na_2O and K_2O . Store these solutions in acid-resistant glass bottles with ground-glass or rubber stoppers.

(d) *Correction solutions.*—Using the CaCl_2 stock solution and the NaCl-KCl stock solution, prepare solutions containing the equivalent of 0, 5, 20, 40, 60, 80, and 100 p.p.m. of Na_2O and K_2O , respectively, and each containing the equivalent of 1,700 p.p.m. of CaO .

3. Calibration of flame photometer

(a) Turn on the instrument, adjust the air pressure to 10 p.s.i. and the propane gas pressure to 5 p.s.i. Adjust the burner so as to give a faintly visible flame 5 to 6 inches high and with $\frac{1}{8}$ -inch cones over the burner grid. These cones should be uniform, quiet, and of a blue or greenish-blue color. Allow the system to warm up for approximately 30 minutes after the current and gas are turned on.

(b) Set the internal-standard dial at zero and adjust the meter reading to zero with the zero adjustment knob.

(c) Find the correct position on the wavelength dial for the element to be determined by pouring into the atomizer a portion of the 100-p.p.m. standard solution of $\text{Na}_2\text{O-K}_2\text{O}$ and moving the selector slowly back and forth on each side of the indicated wave length for the element until the point of maximum deflection is noted. Set the wave-length selector at this point. The coarse and fine gain controls are used to adjust the deflections to the range of 90 to 100.

(d) Pour the 100-p.p.m. standard solution into the atomizer and adjust the controls until the meter reading is 100. Then pour in distilled water and adjust the zero-adjust-

ment knob until the meter reads zero. Repeat these two operations until no adjustment is necessary in going from one to the other.

(e) Next pour into the atomizer the 8 p.p.m. standard solution and note the meter reading to the nearest whole division.² Check the zero reading with distilled water and the 100 reading with the 100-p.p.m. standard solution. If these readings are exactly zero and within one scale division of 100, respectively, the reading for the 80-p.p.m. solution can be considered correct. If the zero reading is not exact, or the 100-p.p.m. reading is not within one scale division of 100, repeat the adjustments in step 3 (d) and take another reading for the 80-p.p.m. solution. Continue until no adjustment of the zero and 100 points is necessary after securing the reading for the 80-p.p.m. standard solution.

(f) In a similar manner, determine readings² for the 60, 40, 20, and 5-p.p.m. standard solutions of $\text{Na}_2\text{O-K}_2\text{O}$.

(g) Plot calibration curves for each oxide using cross-section paper of such type that each division on the ordinate represents meter reading of one unit and each division on the abscissa represents a concentration of 1 p.p.m. (see fig. 1, page 101).

4. Correction curves

(a) Using the correction solutions, determine the apparent Na_2O and K_2O concentration in parts per million as directed for analysis of the samples in steps 6 and 7, with the application of the calibration curves determined in accordance with step 3 (g).

(b) To determine the reagent impurities make a blank determination, following the procedure outlined in step 5 for the preparation of the sample and in steps 6 and 7 for the determination of Na_2O and K_2O . The meter readings obtained are converted to parts per million (see step 3 g) and the latter values represent the effect of the 1,700-p.p.m. CaO in addition to the reagent impurities. Subtract from the value for each oxide the value obtained for the correction solution containing no added NaCl or KCl . These values represent the effect of the reagent impurities alone.

(c) Add the effect of the reagent impurities as obtained in step 4 (b) to the apparent sodium and potassium concentration obtained in step 4 (a). Plot the resulting apparent concentrations as abscissas and the known true value for the alkali oxide as ordinates. This gives a correction curve which includes the reagent blank. Once obtained, it is not necessary to recheck the curve except when the reagents are changed or when some change is made in the instrument.

5. Preparation of sample

(a) Place 0.5000 ± 0.0005 gm. of finely ground sample (passing No. 100 sieve) to an agate mortar, add 0.500 gm. NH_4Cl , and grind until completely mixed.³ Add 4.0 gm. CaCO_3 to the mixture, grind until well mixed, and transfer the mixture to a J. Lawton

² For meter readings of all solutions in the lower half of the scale, the apparatus is sufficiently stable and sensitive that readings may be made to the nearest half division.

³ Close control of the quantity of NH_4Cl is necessary as it directly affects the amount of calcium which goes into solution as the chloride.

th platinum crucible containing approxi-
ely 0.5 gm. CaCO_3 in the bottom. Rinse
mortar and pestle with approximately 0.5
 CaCO_3 and add to the crucible. Cap the
cible, tap it gently to cause the powder to
le, and place it in a slightly inclined position
refractory cylinder provided with a suit-
hole to receive the crucible.

b) Heat the portion of the crucible within
cylinder by means of a fish-tail flame
ed well below the crucible for about 15
utes or until the odor of ammonia is no
ger perceptible. The heat should not be
ong enough to cause vapors of NH_4Cl to
ape. The crucible should be rotated at
ervals during the early stages of the ignition.
dually increase the heat until the crucible
bright red and maintain this temperature
40 to 60 minutes.⁴ Allow the crucible to
l and transfer the sintered mass to a 250-ml.
serole. Pour hot water into the crucible
digest until all remaining matter can be
shed out into the casserole or until it is
roughly extracted. Slake the sintered
e in the casserole by adding cautiously a
milliliters of water, then add approxi-
ately 50 ml. more and digest on the steam
h until the cake is thoroughly disintegrated
o 8 hours). Disintegration may be aided
grinding with an agate pestle during the
estion period.

c) After the cake has completely disin-
terated, adjust the volume of liquid in the
serole to approximately 50 ml., evaporating
necessary. Heat the covered casserole to
ling on a hot plate, let the solids settle,
l rapidly filter into a 250-ml. volumetric
k made of acid-resistant glass. Add 30
of hot water to the casserole, break up
lumps by gentle pressure with a pestle
glass stirring rod, heat to boiling, let settle,
l filter. Repeat the extraction with 30
of water three more times (a total of
r 30-ml. washings). Transfer the bulk of
residue to the filter paper with a minimum
ount of hot water, and wash the residue
the paper once or twice with hot water so
to bring the filtrate level to within several
timeters of the neck of the flask.⁵

Add three or four drops of brom-thymol
e indicator to the flask and then add con-
centrated HCl drop by drop until one drop
uses the indicator to change color. Cool
flask and its contents to room temperature,
l sufficient water to bring the liquid level
the calibration mark, and mix well. This
ution is then used for the flame-photometer
alysis.

Determination of sodium oxide

(a) Warm up the apparatus and calibrate
the sodium determination, following the
tructions given in step 3.

(b) Add a portion of the sample solution
the atomizer and record the meter reading
the nearest whole division.⁶ Then select
standard solution which gives a meter
ading closest to the unknown and record its

In order to obtain a bright red heat, it may be necessary
replace the fish-tail burner with one of the Meker type.
The final volume of the filtrate must be as nearly constant
possible in order to insure a uniform calcium concentration.
See footnote 2, p. 100.

reading. This latter value should agree to
within one division on the meter scale with
the average value established during the
calibration of the apparatus. If it does not,
reset the meter needle to the original calibra-
tion point by use of the fine-gain control.
Check the zero and 100 division points with
the appropriate standard solutions. Finally,
alternate the use of the unknown solution and
the closest standard until readings for the
unknown agree to within one division on the
meter scale and the reading for the standard
similarly agrees with the calibration point.
Record the average of the last two meter
readings obtained with the unknown solution.

7. Determination of Potassium Oxide

Follow the same procedure as for Na_2O
(step 6) except that the instrument is cali-
brated with the wave-length selector set at
the point of maximum response to K_2O by
use of the 100-p.p.m. standard solution.

8. Calculation of results⁷

(a) From the recorded averages of the meter
readings for Na_2O and K_2O read the concen-
tration to the nearest half division from the

⁷ These calculations are based on a 0.500-gm. sample. For
samples containing greater than 5 percent of either alkali
oxide a smaller sample must be used and the calculations
varied accordingly.

calibration curve (step 3g). This is the ap-
parent concentration of the alkali oxide in
parts per million. Convert this value to the
corrected or true concentration by use of the
correction curve obtained in step 4.

(b) Calculate the percentage of alkali oxide
to the nearest 0.02 percent as follows:

$$\text{Alkali oxide, percent} = \frac{C}{20}$$

Where C = true concentration in p.p.m. (from
correction curve), and

$$20 = \frac{0.5 (\text{weight of sample})}{250 (\text{volume of solution})} \times \frac{1,000,000}{100}$$

Constant Calibration Check Needed

Careful calibration and a constant check on
the calibration of the flame photometer are
essential for accurate results. The calibration
depends on the constancy of a large number
of the system components, such as voltage,
tube sensitivity, gain control, gas pressure,
air pressure, atomizer efficiency, and burner
adjustment. The calibration must be made
before each run and certain calibration points
checked during a run as directed. However,
with the instrument operating normally when
the zero and 100-p.p.m. points are properly
set, the balance of the calibration points

Table 1.—Example of data obtained in calibrating the flame photometer with standard solution¹

Concentra- tion of Na_2O or K_2O in standard solution	Meter reading (in divisions) for—							
	Na_2O determination				K_2O determination			
	Test 1	Test 2	Test 3	Avg.	Test 1	Test 2	Test 3	Avg.
P.p.m.								
5	5	5	4.5	5	3	3	3	3
20	22	21	21	21	18	17	17	17
40	46.5	46.5	45.5	46	39.5	38.5	39.5	39
60	70.5	70	70	70	64	63.5	64	64
80	87	87	87.5	87	84	83	83	83
100	² 100	-----	-----	² 100	² 100	-----	-----	² 100

¹ The standard solutions were prepared as given in step 2(c) of the method of analysis, page 100.

² Apparatus was adjusted to give a full-scale deflection of 100 divisions with the standard solution containing 100 p.p.m. of the alkali oxide.

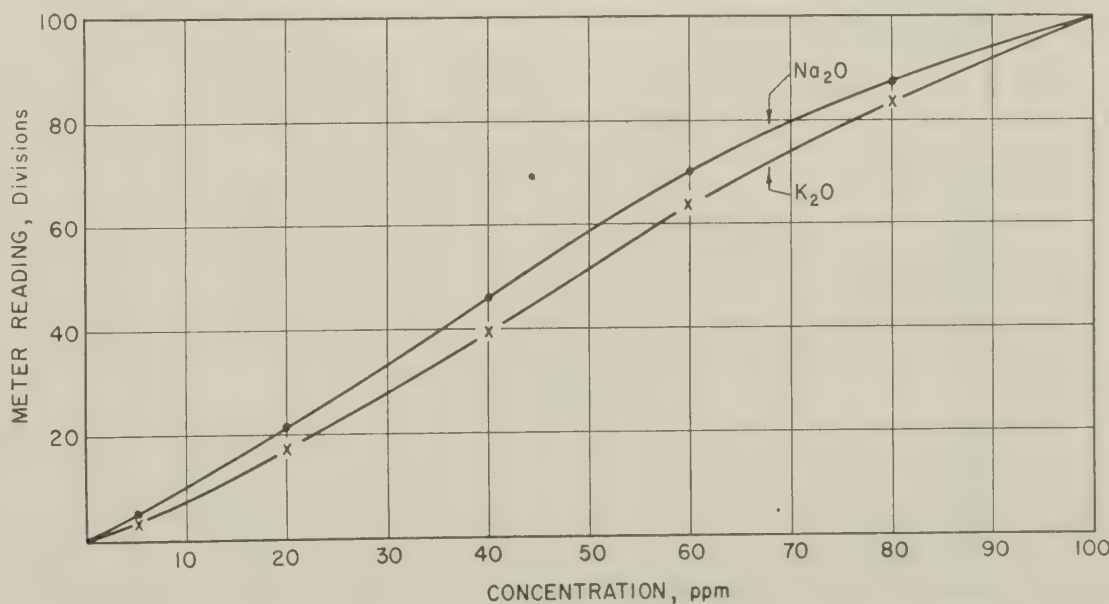


Figure 1.—Typical calibration curves for determination of sodium oxide and potassium oxide with the flame photometer, using the direct-intensity method.

Table 2.—Suggested form for recording test data in flame-photometer analyses

Sample identification	Na ₂ O determination (a similar table is used for K ₂ O determination)						
	Meter reading (in divisions) of—				Concentration		
	Nearest standard	Unknown			Apparent	True	On basis of sample
		Test 1	Test 2	Average			
					<i>P.p.m.</i>	<i>P.p.m.</i>	<i>Percent</i>

usually remain essentially constant so that it may not be necessary to draw a new calibration curve for each run. Also, during the course of a run there is usually very little change in the calibration unless the atomizer is clogged or the burner flooded, in which cases the trouble is immediately apparent. Thus, the practical accomplishment of the conditions necessary for accurate results is not difficult.

Table 1 shows an example of the data obtained in calibrating the instrument. These data are plotted in figure 1. Table 2 presents a convenient form for recording the test data obtained in analyzing unknown samples.

Calcium Interference

The effects of the interference of other constituents on the alkali determination by flame photometry have been described (3, 6) for instruments using color filters to isolate the wave lengths. However, the instrument used in this study employs a two-prism monochromator for wave-length separation and, therefore, it is likely that the interferences may be different than when color filters are used.

The elements to be concerned with are sodium, potassium, and calcium. The other elements which may occur in natural silicates—iron, aluminum, barium, lithium, magnesium, manganese, strontium, and chromium—have a negligible effect. Furthermore, because of the method of decomposition employed, these constituents will not be present in solution except in very small amounts. Mineral and organic acids will not be present as such to interfere with the results.

Table 3 shows the effects of varying amounts of sodium, potassium, and calcium oxides on the determinations of Na₂O and K₂O. For these tests the instrument was calibrated and the apparent concentration of the alkali in the solution was determined as described in the method of analysis. The results indicate that for the type of solutions employed sodium and potassium do not interfere with each other within the range of concentration studied. However, the calcium ion (shown as CaO), when present in considerable amounts, has a significant inhibiting effect on determinations of both sodium and potassium.

A study was made to determine the concentration of calcium to be expected in test

solutions. Aliquot portions were taken from a group of solutions prepared for the determination of the alkalis by the flame photometer. The amount of calcium in each solution was determined by a standard volumetric method. The results of these tests are given in table 4, the calcium being expressed as equivalent amount of CaO. The range of these results was from approximately 1 to 1,800 p.p.m. with the average being 1,700. Thus, 1,700 p.p.m. of CaO was taken as a suitable expression of the expected calcium concentration in all test solutions. Since data shown in table 3 indicate that the effect of calcium does not change greatly with concentration, deviations from this average value which normally may be obtained are not sufficient to make a measurable change in the interference of the calcium ion.

Table 4.—Concentration of calcium as CaO in test solutions of silicates prepared for flame-photometer analysis

Sample identification	Type of material	Concentration of CaO in test solution
19.....	Trap rock.....	<i>P. p. m.</i> 1,600
20.....	Diorite.....	1,620
21.....	Fly ash.....	1,810
22.....	do.....	1,710
Blank A.....		1,700
Blank B.....		1,730
Average.....		1,700

¹ Volumetric determination with standard KMnO₄ on aliquot portion.

A more complete study was made to show the effect of 1,700 p.p.m. of CaO on sodium and potassium determination for a range of concentrations usually encountered. These analyses were made as before, using the calibration curve obtained with pure solutions of NaCl and KCl. The results are shown in table 5. These data further confirmed the conclusion drawn from the data in table 3 that, for this type of solution, within the range studied, the alkalis did not affect each other. Also, the interference of the calcium ion for a definite concentration of one alkali metal is the same regardless of the concentration of the other alkali. The inhibiting effect of the calcium ion increases as the concentration of the alkali increases. It should be noted that for the lower concentrations of Na₂O, 1,700 p.p.m. of CaO produces a positive error (see tables 3 and 5).

Correction Curve for Calcium

The use of a correction curve to correct for the effect of the calcium ion is a departure from the usual practice in flame-photometer applications. In the usual procedure, corrections would be made by using as standards correction solutions, each of which contains 1,700 p.p.m. of CaO with different amounts of Na₂O and K₂O. A calibration curve constructed from data obtained with these solutions would then automatically correct for the interference. For laboratories concerned with the analysis of this type of silicate materials

Table 3.—Effect of certain constituents on the sodium oxide and potassium oxide determinations with the flame photometer

[parts per million]

Interfering constituent and its concentration	Amount added: None		Amount added: 5 p.p.m.		Amount added: 80 p.p.m.	
	Amount found	Error	Amount found	Error	Amount found	Error
SODIUM OXIDE ¹ DETERMINATION						
K ₂ O: ¹						
5.....	0	0	5	0	80	0
80.....	0	0	5	0	80	0
CaO: ²						
50.....	0	0	5	0	80	0
300.....	0	0	5	0	79	-1
700.....	2	+2	5	0	75	-5
1,200.....	1	+1	6	+1	75	-5
1,700.....	2	+2	7	+2	75	-5
2,200.....	2	+2	7	+2	76	-4
POTASSIUM OXIDE ¹ DETERMINATION						
Na ₂ O: ¹						
5.....	0	0	5	0	80	0
80.....	0	0	5	0	80	0
CaO: ¹						
50.....	0	0	5	0	77	-3
300.....	0	0	5	0	75	-5
700.....	0	0	5	0	74	-6
1,200.....	0	0	4	-1	73	-7
1,700.....	0	0	5	0	72	-8
2,200.....	0	0	4	-1	71	-9

¹ The proper amount of A.C.S. NaCl or KCl was dissolved in water to give the indicated oxide concentration.

² Present in solution as CaCl₂. The proper amount of A.C.S. "low-alkali" CaCO₃ was neutralized with just sufficient concentrated HCl to give the indicated oxide concentration.

Table 5.—Effect of alkali oxides and 1,700 p.p.m. calcium oxide on the alkali determinations with the flame photometer

[parts per million]

Na ₂ O determination								K ₂ O determination							
Amount of Na ₂ O in sample ¹	Apparent Na ₂ O determined when amount of K ₂ O added ¹ (and 1,700 p.p.m. of CaO also added ² in each case) was—						Average apparent Na ₂ O determined	Amount of K ₂ O in sample ¹	Apparent K ₂ O determined when amount of Na ₂ O added ¹ (and 1,700 p.p.m. of CaO also added ² in each case) was—						Average apparent K ₂ O determined
	0 p.p.m.	5 p.p.m.	20 p.p.m.	60 p.p.m.	80 p.p.m.	100 p.p.m.			0 p.p.m.	5 p.p.m.	20 p.p.m.	60 p.p.m.	80 p.p.m.	100 p.p.m.	
0	2	2	1.5	2	1	-----	1.7	0	1	0	1	0	0	-----	0.4
5	6	6	6	7.5	7.5	-----	6.6	5	5	5	5	5	5	-----	5.0
20	20	20	³ 18.5	21	21	-----	20.5	20	15.5	16	15.5	17.5	17.5	-----	16.4
60	56.5	55	³ 52.5	57	56	-----	56.1	60	52	52	52.5	³ 55.5	51	-----	51.9
80	73	74.5	76	77.5	74.5	-----	75.1	80	73	72	³ 68.5	72	72	-----	72.2
100	-----	-----	-----	-----	-----	$\left\{ \begin{array}{l} 95 \\ 95.5 \\ 95.5 \end{array} \right\}$	95.3	100	-----	-----	-----	-----	-----	$\left\{ \begin{array}{l} 90.5 \\ 90.5 \\ 90 \end{array} \right\}$	90.3

¹ Added to solution as A.C.S. NaCl or KCl in calculated amounts to give indicated oxide concentrations.² In solution as A.C.S. CaCl₂, "low-alkali" CaCO₃ was dissolved with concentrated HCl, care being taken to avoid excess HCl.³ Not included in average.

y, this is obviously the simpler procedure. the Public Roads laboratory, however—it is believed the same condition will be in most other laboratories—it is necessary to analyze a variety of materials such as soil cement extracts with water, water analysis, which require the pure NaCl-KCl standard solutions. Thus, these standard solutions are readily available. Inasmuch as the method for determining the alkalis in portland cement by flame photometry already requires a special set of standard solutions (1), it was considered advisable to limit the number of different types of standard solutions. In addition, once the correction curve is obtained for a particular instrument, there is no need of repeating this work unless a change is made in the reagents or in the instrument. Thus, while the use of a correction curve may seem to be at first glance an unnecessary step, for practical laboratory applications it is convenient and economical.

Since the alkali impurities in the reagents used also must be accounted for, the data obtained with the correction solutions alone cannot be used directly as the basis of the correction curve. Blank determinations were made using the method as shown. These gave apparent values of the sodium and potassium concentrations which include the effects of the 1,700 p.p.m. of CaO, in addition to the alkali impurities. Thus it is necessary to subtract from the blank determinations the effect of the calcium ion for zero concentration of the alkali. The resulting value represents the alkali impurities in the reagents, and an overall effect is calculated by adding the value of the blank to each of the values obtained with the correction solution. A curve is then constructed using these apparent values as abscissas and the corrected or true values as ordinates.

For example, the correction curves used for the determinations reported in this article were constructed as follows: The averages for each concentration shown in table 5 are equivalent to the data normally obtained with the correction solutions. Blank determinations showed an average apparent value of 2.5 p.p.m. for Na₂O and 2.0 p.p.m. for K₂O. Table 5 showed the effect of the calcium ion alone (zero concentration of alkali) to be +1.7 p.p.m. for the sodium determination, and +0.4 p.p.m. for the potassium determination. The respective differ-

ences, 0.8 p.p.m. for sodium and 1.6 p.p.m. for potassium, represent the concentration of the alkali resulting from the reagent impurities. The combined effect is obtained by adding these values to the respective average values shown in table 5. These data, given in table 6, were then used to plot the correction curves shown in figure 2.

Comparison with Gravimetric Method

Table 7 shows a comparison between results obtained by an accepted gravimetric procedure and by the flame-photometer method described in this article. A variety of silicates were analyzed, including a large number of soils, in order to obtain as wide a range of alkali content as possible. For most samples there is very good agreement between the flame-photometer and the gravimetric results. For Na₂O, out of 24 samples only 3 showed differences in percentage greater than 0.10. For K₂O, 9 samples showed differences in percentage greater than 0.10, but only 1 of these differences was greater than 0.15. The average difference in percentage for sodium was 0.054 while that for potassium was 0.076. Since in most cases the gravimetric result represents only one determination, there is no

Table 6.—Combined effect of 1,700 p.p.m. calcium oxide and reagent impurities on the alkali determinations with the flame photometer

[parts per million]

Na ₂ O added ⁽¹⁾	Na ₂ O determined ²	K ₂ O added ¹	K ₂ O determined ²
0	2.5	0	2.0
5	7.4	5	6.6
20	21.3	20	18.0
60	56.9	60	53.5
80	75.9	80	73.8
100	96.1	100	91.9

¹ True concentration.² Apparent concentration.

assurance that this result is more accurate than that obtained with the flame photometer.

While data on the reproducibility of gravimetric results are limited, table 8 shows a comparison of duplicate gravimetric results for a few materials. These analyses were made in a routine manner, employing the usual technique with the average amount of care. It is noted that the differences between the results of duplicate tests by the gravimetric method are of the same order as differences between results of the gravimetric and flame-photometer methods.

The differences between gravimetric and flame-photometer test results found in this

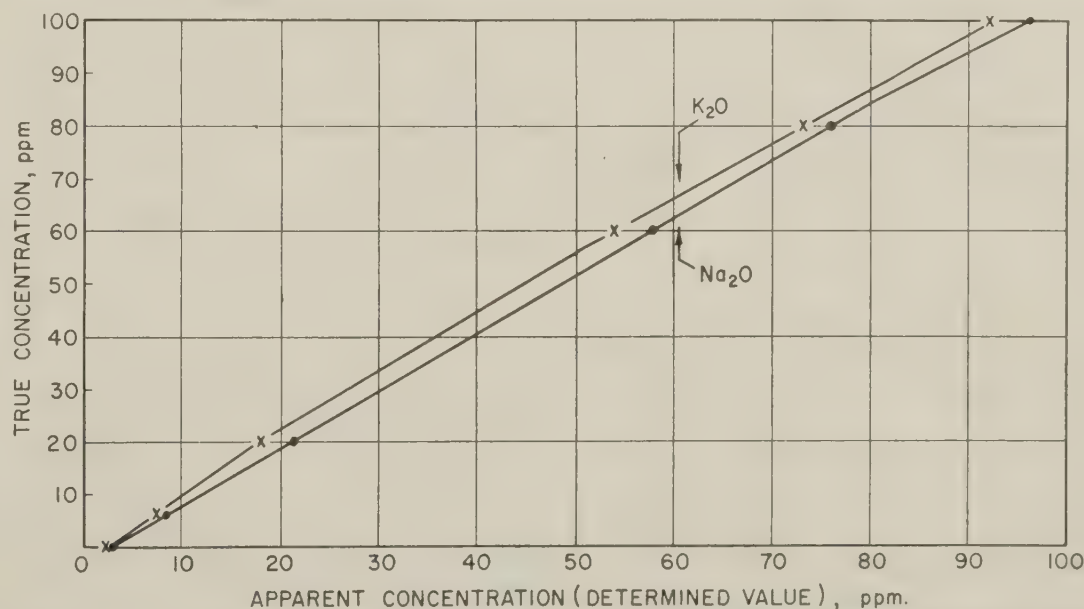


Figure 2.—Correction curves for the combined effect of 1,700 p.p.m. calcium oxide and the reagent blank on the sodium oxide and potassium oxide determinations with the flame photometer.

paper compare favorably with differences reported for other applications of the flame photometer. Barnes and others (2) recently described a method involving the use of an internal standard (lithium) in an instrument using filters to isolate the desired wave length. While their data for clays gave only the total alkali ($\text{Na}_2\text{O} + \text{K}_2\text{O}$) determined by chemical means, their differences are of the same order or slightly higher in most cases than the differences shown in this work.

For portland cement analyses the concentration of the test solution is such that 1 p.p.m. is equivalent to 0.01-percent alkali oxide. Results obtained in the Public Roads laboratory, as well as those which appear in various unpublished reports and in a report by Eubank and Bogue (4), show an average difference in percentage between gravimetric and flame-photometer results of from 0.01 to 0.03 for Na_2O and from 0.02 to 0.03 for K_2O . In the method for siliceous materials the concentration of the test solution is such that 1 p.p.m. is equivalent to 0.05 percent. Thus, while the actual difference reported for portland cement is less, the difference in terms of concentration of test solution in parts per million is approximately the same.

Application to Non-Portland Hydraulic Cements

An interesting observation may be made in connection with the pozzolanic cements shown in table 7. Flame-photometer results for these same cements by the tentative A.S.T.M. method for portland cements (1) gave, for sample 23, 0.09 percent Na_2O and 0.39 percent K_2O , and for sample 24, 0.13 percent Na_2O and 0.59 percent K_2O . These values are considerably less than those obtained by gravimetric means or by the method given here. These and similar cements have alkalies associated with the acid-insoluble residue which are not brought into solution by the tentative A.S.T.M. method for portland cements. Thus, the proposed procedure

(Continued on page 98, third column)

Table 7.—Comparison of results obtained by gravimetric and flame-photometer meth

Sample identification	Material	Amount of Na_2O			Amount of K_2O		
		Gravimetric ¹	Flame photometer	Difference ²	Gravimetric ¹	Flame photometer	Difference ²
		Percent	Percent		Percent	Percent	
1-----	Soil-----	0.15	0.14	-0.01	4.08	4.20	+0.12
2-----	do-----	.07	.08	+0.01	3.76	3.87	+0.11
3-----	do-----	.11	.15	+0.04	.40	.34	-.06
4-----	do-----	.43	.45	+0.02	1.50	1.61	+0.11
5-----	do-----	.84	.82	-.02	2.22	2.18	-.04
6-----	do-----	1.03	1.01	-.02	2.14	2.21	+0.07
7-----	do-----	.72	.82	+0.10	2.06	2.18	+0.12
8-----	do-----	.39	.42	+0.03	1.57	1.56	-.01
9-----	do-----	.50	.52	+0.02	1.38	1.41	+0.03
10-----	do-----	.73	.77	+0.04	2.88	2.94	+0.06
11-----	do-----	.49	.58	+0.09	1.59	1.73	+0.14
12-----	do-----	.92	.93	+0.01	2.00	2.24	+0.24
13-----	do-----	.84	.90	+0.06	2.08	2.18	+0.10
14-----	do-----	.10	.10	.00	.21	.16	-.05
15-----	do-----	.15	.06	-.09	.53	.51	-.02
16-----	do-----	.31	.18	-.13	1.32	1.31	-.01
17-----	Slag-----	.19	.15	-.04	.68	.75	+0.07
18-----	Trap rock-----	2.52	2.77	+0.25	.76	.77	+0.01
19-----	do-----	2.64	2.69	+0.05	.79	.90	+0.11
20-----	Diorite-----	3.90	4.08	+0.18	3.08	3.23	+0.15
21-----	Fly ash-----	.25	.25	.00	2.34	2.34	.00
22-----	do-----	2.74	2.69	-.05	.81	.96	+0.15
23-----	Pozzolan cement-----	.21	.19	-.02	1.23	1.24	+0.01
24-----	do-----	.16	.15	-.01	.86	.89	+0.03
Average-----	-----	-----	-----	.054	-----	-----	.076

¹ Analyses made by J. Lawrence Smith method of fusion, with potassium being determined as K_2PtCl_6 and sodium determined by difference from the weight of the combined sulfates.

² Calculated by subtracting the gravimetric from the flame photometer result.

Table 8.—Comparison of results obtained in duplicate tests by the gravimetric determination of sodium and potassium oxide ¹

Sample identification	Material	Amount of Na_2O found			Amount of K_2O found		
		Test 1	Test 2	Difference	Test 1	Test 2	Difference
		Percent	Percent		Percent	Percent	
1-----	Soil-----	0.14	0.16	0.02	4.08	4.08	0.00
3-----	do-----	.09	.14	.05	.38	.43	.05
4-----	do-----	.51	.36	.15	1.55	1.45	.10
17-----	Slag-----	.21	.17	.04	.66	.48	.18
18-----	Trap rock-----	2.55	2.50	.05	.76	.76	.00
19-----	do-----	2.65	2.64	.01	.81	.77	.04
20-----	Diorite-----	3.83	3.98	.15	3.17	3.00	.17
21-----	Fly ash-----	.23	.27	.04	2.29	2.38	.09
23-----	Pozzolan cement-----	.21	.21	.00	1.17	1.29	.12
24-----	do-----	.17	.15	.02	.85	.88	.03
Average-----	-----	-----	-----	.053	-----	-----	.078

¹ Samples analyzed by J. L. Smith method of fusion with CaCO_3 . Potassium determined as K_2PtCl_6 and sodium determined by difference from the weight of the combined sulfates.

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AS OF OCTOBER 31, 1950

(Thousand Dollars)

STATE	UNPROGRAMMED BALANCES	ACTIVE PROGRAM						TOTAL		
		PROGRAMMED ONLY			PLANS APPROVED, CONSTRUCTION NOT STARTED			CONSTRUCTION UNDER WAY		
		Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles
Alabama	\$11,813	\$12,354	\$6,333	282.7	\$4,954	\$2,354	155.7	\$13,921	\$6,249	306.1
Arizona	392	1,923	1,374	44.5	1,897	1,265	26.2	5,793	4,137	120.3
Arkansas	1,531	9,168	5,234	227.0	3,152	1,538	83.6	17,753	8,759	462.7
California	2,655	23,715	9,088	177.8	4,847	2,363	22.6	44,665	21,994	277.2
Colorado	1,559	4,189	2,261	74.0	2,097	1,177	61.2	15,203	8,824	316.0
Connecticut	1,373	10,322	4,752	23.4	2,212	1,274	2.4	5,379	3,080	10.2
Delaware	1,345	618	318	21.3	1,409	703	4.5	5,471	2,620	41.6
Florida	2,366	14,424	7,325	387.0	8,936	4,422	225.1	12,901	6,452	256.3
Georgia	574	17,922	9,173	398.2	9,971	4,935	115.5	27,933	13,778	664.3
Idaho	3,707	8,959	5,642	292.2	915	561	60.9	7,058	3,835	141.4
Illinois	20,376	39,092	20,932	324.8	10,758	5,385	76.6	51,108	25,029	365.3
Indiana	6,648	32,943	16,004	165.3	6,142	3,655	24.5	16,009	7,948	94.1
Iowa	2,951	8,903	3,409	222.7	3,349	1,182	110.9	17,455	8,254	572.0
Kansas	3,434	9,520	3,903	968.7	3,700	1,878	449.5	12,762	6,385	620.1
Kentucky	1,491	11,512	5,565	103.7	6,034	2,978	107.9	17,675	8,703	321.1
Louisiana	3,294	20,827	9,227	165.7	5,659	2,594	60.9	20,296	10,744	261.4
Maine	1,290	7,302	3,866	84.2	7,789	3,998	11.1	6,348	3,359	61.1
Maryland	1,313	6,714	3,124	18.7	2,889	1,165	15.5	13,234	6,175	22.837
Massachusetts	2,476	3,390	896	7	7,018	3,602	6.0	67,871	33,078	69.7
Michigan	2,431	17,043	8,775	454.1	7,484	3,922	134.9	41,014	16,889	409.7
Minnesota	1,757	7,329	4,361	752.6	1,935	954	215.5	22,180	12,009	677.9
Mississippi	3,882	14,804	7,791	529.3	3,828	1,839	127.2	6,932	3,546	237.8
Missouri	5,226	29,582	16,228	871.3	6,806	2,898	214.8	30,020	14,561	481.3
Montana	4,572	14,853	7,673	505.1	2,301	1,389	13.4	10,577	6,418	296.7
Nebraska	4,505	16,152	8,446	533.0	4,531	2,048	98.9	10,388	5,648	285.6
Nevada	1,644	3,423	2,819	117.3	925	765	29.6	3,184	3,216	105.1
New Hampshire	1,727	3,404	1,880	28.4	1,065	486	7.7	4,350	2,081	37.6
New Jersey	2,526	3,288	1,532	6.5	2,970	1,331	5.1	18,087	8,578	27.6
New Mexico	987	3,754	2,398	115.1	5,207	3,331	143.6	6,465	4,226	185.6
New York	24,816	63,536	31,347	180.0	29,461	11,369	69.5	103,468	49,045	187.5
North Carolina	991	18,123	8,686	458.4	5,072	2,485	88.0	23,506	11,116	583.3
North Dakota	2,224	7,642	3,949	1,052.1	3,694	1,692	323.3	4,917	2,456	519.9
Ohio	8,500	26,531	12,913	281.5	20,677	11,482	156.5	53,280	25,302	280.3
Oklahoma	2,415	10,431	6,088	96.4	10,015	5,266	199.4	18,733	8,734	451.1
Oregon	639	3,597	2,024	54.2	2,123	1,218	30.0	8,485	4,929	123.8
Pennsylvania	4,330	17,729	8,775	25.5	10,309	5,154	49.9	73,509	36,284	193.6
Rhode Island	248	6,159	3,079	49.6	1,853	989	3.9	12,155	6,149	10.1
South Carolina	1,919	9,717	4,937	227.8	1,523	643	66.7	8,767	4,604	292.2
South Dakota	1,028	7,153	4,051	673.3	1,747	1,028	162.1	10,621	6,451	789.1
Tennessee	1,116	12,713	6,162	288.0	6,493	3,030	105.0	18,594	8,485	362.9
Texas	2,175	3,269	1,678	216.0	12,964	6,918	318.7	48,473	22,707	1,219.2
Utah	1,417	3,946	2,888	92.3	675	500	24.3	5,968	4,358	183.4
Vermont	933	2,284	1,268	38.4	581	292	6.4	5,575	2,609	51.6
Virginia	4,272	21,455	10,628	488.1	6,793	3,340	186.2	13,253	6,477	194.5
Washington	402	11,975	4,941	74.8	2,744	1,327	36.8	18,652	9,030	171.7
West Virginia	722	16,952	7,084	135.0	2,330	1,193	45.0	8,950	4,543	77.7
Wisconsin	7,856	17,556	9,234	262.9	1,923	983	91.1	16,278	8,204	384.9
Wyoming	399	1,846	1,223	34.5	939	610	12.0	5,596	3,404	163.7
Hawaii	665	8,228	3,648	19.9	3,158	1,417	7.6	3,342	1,642	15.8
District of Columbia	1,487	4,150	2,075	4.1	899	662	1.8	1,240	619	1.8
Puerto Rico	1,848	13,157	6,023	66.2	2,077	870	6.1	10,024	4,220	37.7
TOTAL	169,247	645,578	323,098	12,694.3	251,800	123,960	4,601.6	1,006,112	497,911	14,049.7
								1,903,490	944,969	31,345.6

